The WELDING JOURNAL

JULY 1953

IN THIS ISSUE

Factors in the Selection of Welding Processes 585
Cone Arc Welding 597
Resistance Welding Aircraft Stainless Steel 603
High-Pressure Gas Compressor Bottles 612
Inspection Techniques for Quality Welding 614
Welding Research Problems 305-s
Welded Hatch Cover Design 316-s
Behavior in Transition Temperature Zone 325-s
Mechanics of the Explosion Bulge Test 333-s
Structural Failures in Welded Ships 342-s
Copper in Type 347 Weld Metal 347-s
Table of Contents 583
Index to Advertisers 676

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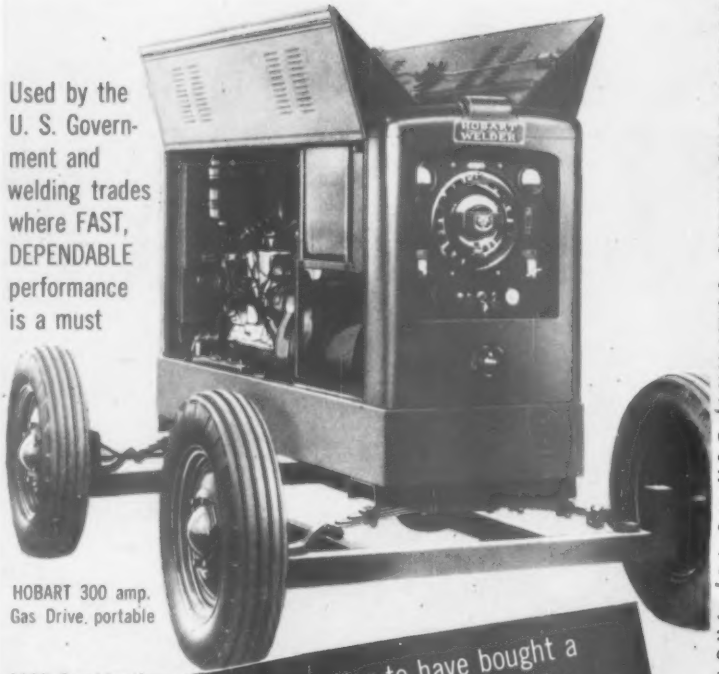

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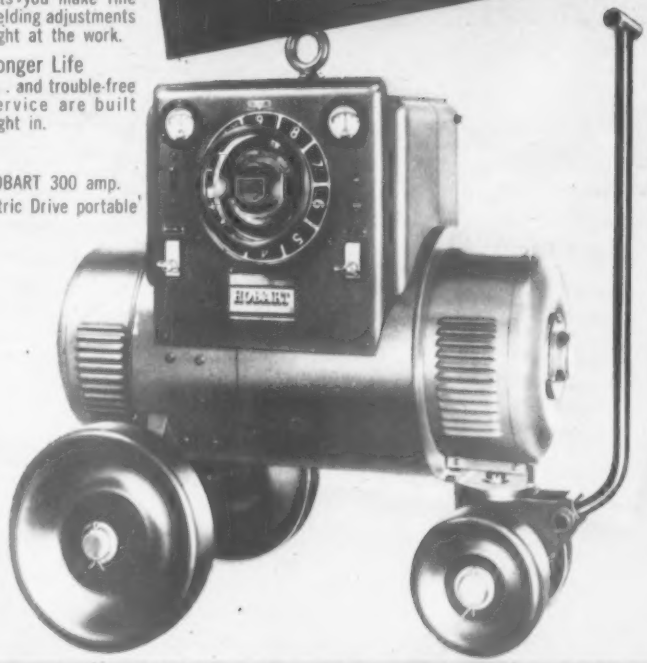

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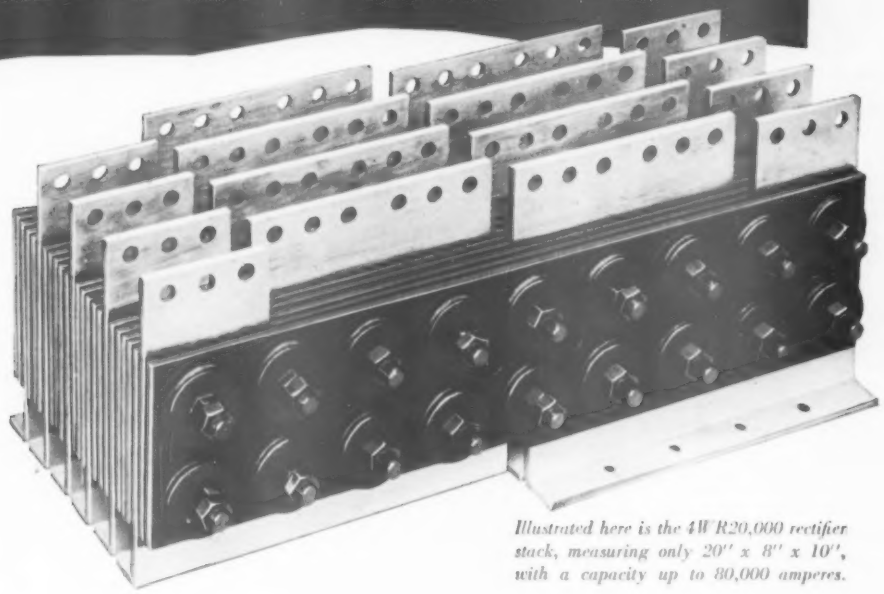

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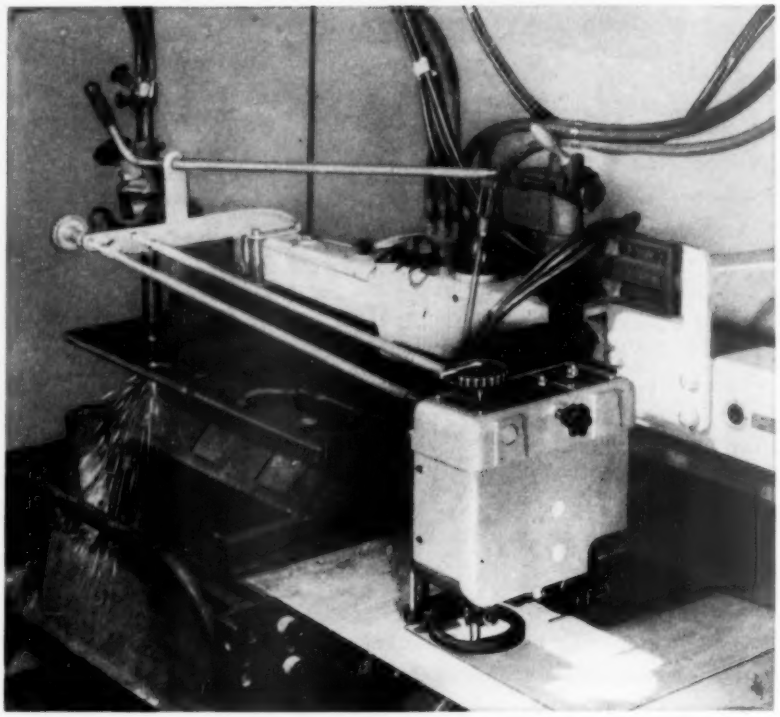

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The WELDING JOURNAL

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TECHNICAL PAPERS, ITEMS AND REPORTS

Factors in the Selection of Welding Processes, by John J. Chyle ... 585
Cone Arc Welding, by P. Patriarca and G. M. Slaughter ... 597
Current Welding Literature ... 602
Resistance Welding Applications in Aircraft Stainless Steels, by D. O. Samuelson ... 603
Stress Corrosion Cracking of Welds ... 611
Welding Design for High-Pressure Gas Compressor Bottles, by Carl Wurgler ... 612
Inspection Techniques for Quality Welding, by Lew Gilbert and W. B. Bunn ... 614

PRACTICAL WELDER AND DESIGNER

Provide for Expansion and Contraction, by J. A. Fluharty ... 620
Baldwin Builds World's Largest Split Die Forging Press ... 622
Welding Time on Minesweeper Stacks Cut in Half ... 624
Joining of Copper by Use of Heliwelding, by H. A. Huff, Jr ... 625
Unionmelt Welding Helps Move Mountains ... 626
Better Bridges By-Pass Tougher Traffic Tangles ... 627
Rotating Electrode ... 630
Stud Welding Used in Farm Machinery ... 631
Protect the Part During Welding ... 632

SOCIETY AND RELATED EVENTS

Society News ... 633
Tentative Program Fall Meeting ... 634
News of the Industry ... 638
New Literature ... 648
Personnel ... 654
New Products ... 656
Employment Service Bulletin ... 666
Section News and Events ... 668
Abstracts of Current Welding Patents ... 673
List of New Members ... 675
Index to Advertisers ... 676

WELDING RESEARCH SUPPLEMENT

Current Welding Research Problems ... 305-s
Considerations of Welded Hatch Corner Design ... 316-s
HW Collection of Reference Radiographs of Welds ... 324-s
Statistical Analysis of Behavior in the Transition Temperature Zone, by R. W. Vanderbeck, H. D. Wilde, R. W. Lindsay and C. Daniel ... 325-s
Mechanics of the Explosion Bulge Test, by Carl E. Hartbower ... 333-s
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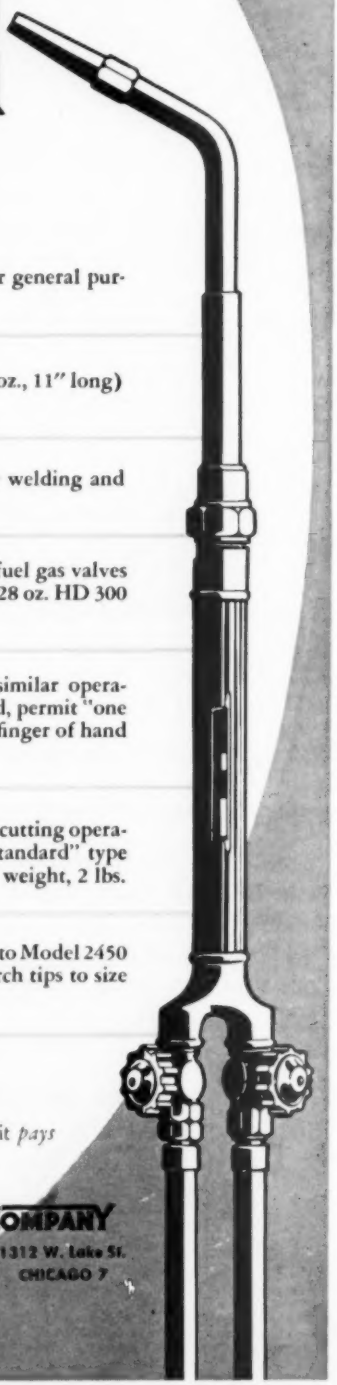

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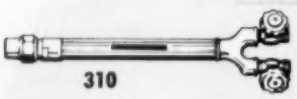
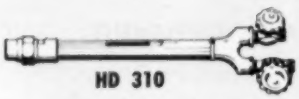
 310	A medium weight and length torch (21 oz., 11″ long) for all around use.
300	A long (14″) torch for users of larger welding and heating nozzles; weight 24 oz.
 HD 310	Heavy duty models with high capacity fuel gas valves for large gas flows. HD 310—11″ long, 28 oz. HD 300—14″ long, 32 oz.
P 310	Especially designed for pipeline and similar operations. Gas control valves, at forward end, permit "one hand" adjustment with thumb and forefinger of hand holding torch. 9″ long, 22 oz.
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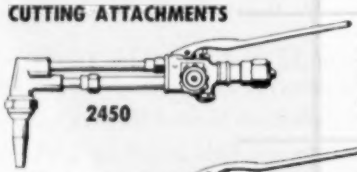
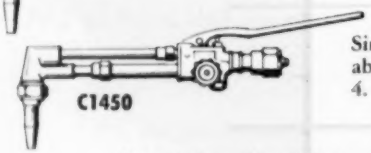
 2450	Handles a full range of general purpose cutting operations up to approximately 8″. Uses "Standard" type cutting tips up to size 5. Length is 13″; weight, 2 lbs.
 C1450	Similar in size, weight and construction to Model 2450 above, but designed for smaller "C" torch tips to size 4. Cuts to approximately 6″.

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The WELDING JOURNAL

volume 32 July 1953 number 7

Factors in the Selection of Welding Processes

The selection of the right welding process calls for an evaluation of eight key factors which are described

by John J. Chyle

WELDING, in its broadest interpretation, is a method of joining metals. Of the relatively few methods used in the joining of metals, such as riveting, bolting and clamping, welding is unquestionably the most important method used in industry today.

In the field of welding technology, a tremendous amount of research investigation has been carried out which has led to a marked improvement in many of the older processes, and has also stimulated the invention of new processes, some of which are less than ten years old. Research and development of welding processes is continuing, and further improvements in existing processes and inventions of new processes are to be expected in the future.

The various welding processes which have been developed can be classified according to the source of heat, application of pressure or the addition of filler metals. The classification which has been adopted by the AMERICAN WELDING SOCIETY is based upon a group of eight distinct processes, and each group is further subdivided so that there are a total of 37 separate welding processes. This classification is shown on the Master Chart, Fig. 1. Each of these 37 welding processes could be further subdivided as to whether they are manual or automatic, and whether alternating or direct current is used. This chart, which was prepared four or five years ago, does not include the latest modifications of some of these processes, such as mash welding or cold-pressure welding. The classification as shown is based on the given characteristics of the processes, and is divided into eight distinct groups, which are as follows in the order of their importance.

1. Arc welding.
2. Resistance welding
3. Gas welding
4. Brazing
5. Forge welding

John J. Chyle is connected with the A. O. Smith Corp., Milwaukee, Wis.

Presented at the SAE Summer Meeting, Ambassador and Ritz-Carlton Hotels, Atlantic City, N. J., June 1-6, 1952, and at the Western Metal Congress, Los Angeles, Calif., Mar. 23-27, 1953.

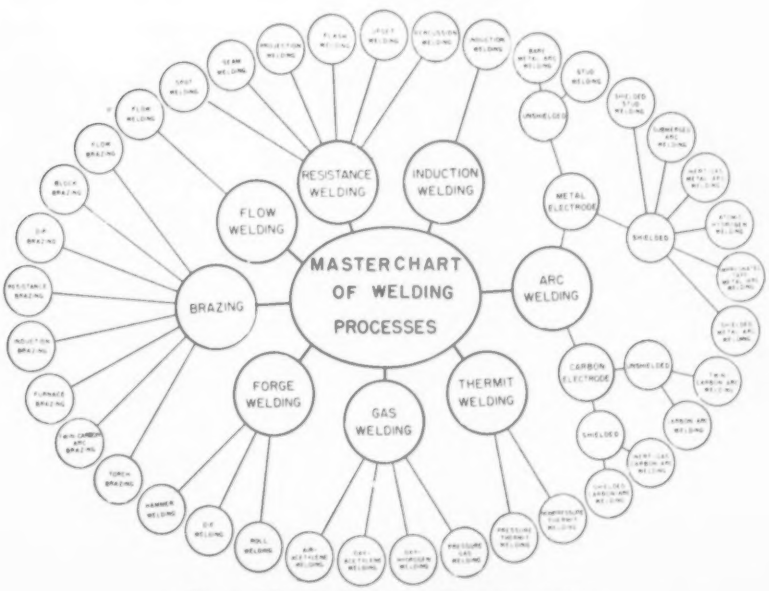

Fig. 1 Master chart of welding processes

6. Thermit welding
7. Induction welding
8. Flow welding

A further breakdown of these eight groups is shown in Figs. 2–5. For the purpose of this discussion we will consider only the most important processes which are in commercial use today.

In the arc welding group we will consider only the metal electrode process and will further limit it to the shielded-metal-arc welding process, using covered electrodes, the atomic hydrogen process, the inert-gas-metal arc process and the submerged arc process.

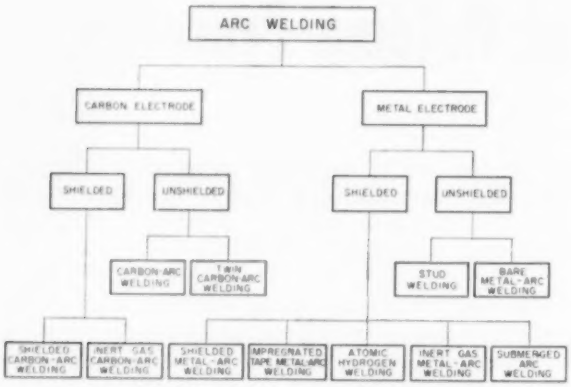

Fig. 2 Subdivision of arc-welding processes

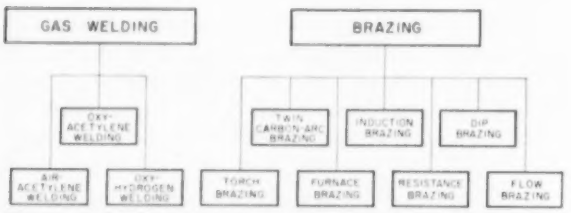

Fig. 3 Subdivision of gas welding and brazing processes

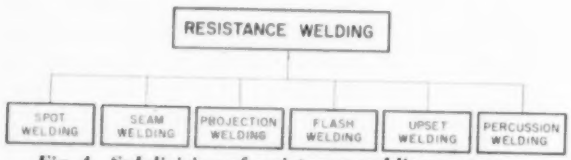

Fig. 4 Subdivision of resistance-welding processes

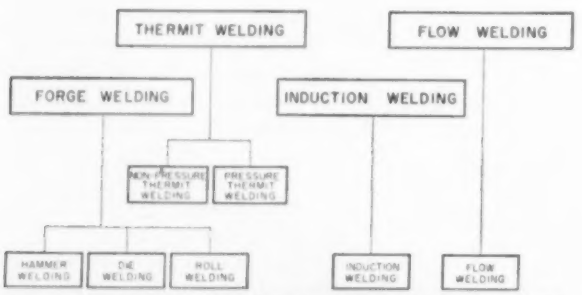

Fig. 5 Subdivision of forge-welding, thermit-welding, induction-welding and flow-welding processes

In the resistance welding group we will consider spot welding, seam welding, projection welding and flash welding.

In the gas welding group we will consider only oxy-acetylene welding.

In the brazing group we will discuss only the torch brazing and furnace brazing processes.

In forge welding we will mention only roll welding.

In the thermit welding group we will mention only the nonpressure welding processes.

While other processes are shown on the chart and discussed in some detail, we have selected only those which are of commercial importance and widely used.

With the large number of individual processes, it is therefore obvious that this discussion can only be a guide to help in the selection of the most suitable welding process. The selection must be based on the most economical use of materials and labor. The product to be welded must fulfill the engineering design and service requirements, and where several welding processes are applicable, the process resulting in the lowest cost must be used.

The factors in the selection of the most suitable welding process will depend on the following:

1. Engineering design and service requirements of the product.
2. Inherent characteristics differentiating the various welding processes.
3. Characteristics of the welds made by the various processes.
4. Composition of metals to be welded.
5. Welding joint design.
6. Production rate.
7. Power availability.
8. Economics of the process.

I. ENGINEERING DESIGN AND SERVICE REQUIREMENTS OF THE PRODUCT

The first consideration must be given to the welded product. Before a satisfactory design can be made, it is necessary to know the service requirements of the product. It is necessary to know the magnitude and distribution of the loads or stresses to be carried—whether oil- or watertightness is involved, operating requirements, pressures; what corrosion, if any, will be encountered, the required life of the structure, the appearance requirements, if any; the temperature conditions under which the product will be exposed, and the mechanical properties which are necessary for its successful performance. Only after the service requirements have been given the proper consideration and study is it possible to determine the material which can be used in the most economical manner. With the selection of material, based on the service requirements, and the engineering design which will depend on its

functional operation, it is then possible to consider the other factors before a final selection can be made as to the most economical welding process applicable to the product.

The guide which must be followed at all times in the selection of the welding process is that the welded product must have such qualities that the service requirements are adequately fulfilled. At all times the guiding decision must be based on the cost of welding, striving for the lowest cost consistent with adequate fulfillment of the service requirements. The decision of what constitutes adequate quality for service requirements is sometimes difficult to determine, and in some cases may require extensive investigation by corrosion testing, proof loading, fatigue testing, etc.

Consideration must be given to:

1. Operating temperatures and pressures.
2. Mechanical properties.
3. Physical properties.
4. Chemical properties.
5. Types of loading.

The operating temperatures will determine to a large extent the composition of the metal or alloy which will be most suitable and economical for the service requirements. The mechanical properties which are required in the product must be known so that the welding process which will produce a welded joint to comply with the required mechanical properties can be used. It is important to know the tensile strength, the yield strength, and ductility, as expressed by elongation and reduction of area, of the parent stock and weld metal. Other mechanical properties such as impact strength, notch toughness and fatigue strength may also be of importance, and consideration for these must be given for both weld and the parent material.

With regard to physical properties, it is important to know whether the weld metal must have characteristics similar to those of the parent stock. The physical properties to be considered are:

1. Hardness.
2. Electrical conductivity.
3. Thermal conductivity.
4. Magnetic.

The chemical composition of the weld metal must be given consideration since in some welding processes the chemistry or composition of the weld differs from the parent stock to a large extent. Where corrosion is an important factor, composition of the weld metal is critical and may vary widely depending upon the welding process that is used.

The type of loading must be given serious consideration in the engineering design of the product in order to obtain the proper distribution of stresses. The type of loading or stress application can be classified as:

1. Static.
2. Dynamic.
3. Vibratory.
4. Fatigue.
5. Torsional.

Under severe loading conditions it may be necessary for stress analysts to give consideration to stress distribution in order that the most efficient design can be utilized. Under some conditions of loading, it is important that notch effects resulting in stress concentration must be avoided.

II. INHERENT CHARACTERISTICS DIFFERENTIATING THE VARIOUS WELDING PROCESSES

After the preliminary design has been considered from the standpoint of meeting service conditions, and the material has been selected, further consideration must also be given to the inherent characteristics of the welding process, the quality of the welds produced by the various processes, the welding joint design, production rate, power availability and the economics of the process.

A knowledge of the inherent characteristics differentiating the various welding processes is of importance to the welding engineer in order that the most suitable welding process can be selected. Under this factor one must consider:

1. Source of heating.
2. Type of shielding.
3. Application of pressure.
4. Addition of filler metal.
5. Completion of the joint.
6. Preparation for welding.
7. Practical aspects of inspection.

(*A*) *Source of Heat*

The source of heating characterizes many of the welding processes. Heat from electric power is created by resistance to flow of electric current. This is represented by spot welding, seam welding, projection welding, flash welding and upset welding. Heat may also be produced by an electric arc, and this is represented in the shielded-metal-arc welding process, the atomic hydrogen process, the inert-gas-metal-arc process, and the submerged-arc welding process. Heat may also be created by a discharge of stored electrical energy, and this is illustrated by the percussion welding process.

A second source of heat may be from the combustion of gases such as oxygen with acetylene, with hydrogen or with other hydro-carbon gases. The oxyacetylene welding process represents this group.

Heat may also be generated from the combustion of coal, carbon or other solid combustible material.

Forge welding is an example where charcoal, coke or coal is used for heating the metal parts up to a welding temperature.

Heat may also be created by a chemical reaction, which is illustrated by thermit welding. In this proc-

ess the heat generated is caused by the chemical reaction taking place between aluminum powder and iron oxide.

(B) *Type of Shielding*

Welding processes can also be differentiated by the type of shielding that is used to protect the molten metal from contamination with atmospheric gases. For many welding processes, shielding of the hot weld metal must be adequately effective to preserve the metallurgical quality of the weld, preventing any deleterious action of oxygen and nitrogen in the air combining with the weld metal. The shielding of weld metal may be by:

1. Gases.
2. Liquid flux.
3. Solid granular flux.

The protection of the hot metal against contamination is usually accomplished by gas shielding. Inert gases such as helium and argon are extremely effective in protecting the molten metal from oxygen and nitrogen in the atmosphere. Reducing gases such as hydrogen and carbon monoxide can also be effectively used to prevent oxidation and nitriding of the molten metal. A good example of reducing gases is the atomic hydrogen process which is used for welding stainless steel, aluminum and many other metals where protection against oxygen and nitrogen is extremely important.

In the bare-metal-arc welding process no special gas for shielding is used, and molten metal is exposed to the atmosphere.

Another method of shielding is by liquid fluxes. In the oxy-acetylene brazing process the flux which is applied as a solid material is converted to a liquid by the heat of the welding process and this liquid on top of the molten metal shields the metal against contamination from the atmosphere.

Another method of shielding is by the use of solid granular flux material. The process which employs this type of shielding, and is widely used, is known as the submerged-arc welding process. In this process the oxygen and nitrogen of the air are excluded by the granular flux surrounding the molten metal. In the arc zone the granular flux becomes a molten blanket covering the hot weld metal and protects it from the oxygen and nitrogen of the air.

(C) *Application of Pressure*

Welding processes are also characterized by the application of pressure. Processes differ according to the method of pressure application. In some processes pressure is an important factor in the welding operation, while in others pressure is not required. Flash welding is a process in which pressure is of prime importance in the operation of the process.

Processes which do not require pressure are, in general, the arc-welding processes such as the shielded-metal-arc, inert-gas metal-arc and submerged arc.

All of the resistance-welding processes require pressure. The success and quality of the weld will depend largely on the application of the correct amount of pressure at the proper time in the welding cycle.

In some processes pressure is applied intermittently, while in others it is applied as a single blow and in still others, the application is of constant duration.

(D) *Addition of Filler Metal*

The welding processes differ radically in the addition or omission of filler metal. In some processes the addition of filler metal is made by means of a bare filler wire, as in oxy-acetylene and atomic hydrogen welding processes. The metal is added in rod or wire form to fill a welding groove. In the shielded-metal-arc welding process, the filler wire is a covered metal electrode which is the source of the deposited metal.

In other processes, no addition of filler metal is required. The resistance welding processes are of this type, and include spot, seam and flash welding.

(E) *Completion of Joint*

Welding processes may also be characterized according to the method of completion of the joint. A welding joint may be completed simultaneously or in a progressive manner. Welding grooves may be completed by depositing weld metal in a number of layers, or the entire weld may be made simultaneously in one operation. An example of progressive welding is the welding of heavy sections where a "V" or "U" groove joint is used and the welding is performed with covered electrodes, and is done manually.

In flash welding the entire weld is completed simultaneously by the application of heat and pressure.

(F) *Preparation Requirements for Welding*

Welding processes differ also in the preparations required for welding. For many of the arc-welding processes the welding groove must be prepared by either machining or gas scarfing of the joint. For some welding processes the surface of the metal must be clean for good electrical contact, as in resistance-welding processes.

The flash-welding processes require clean metal surfaces at the electrode contact areas, in order that satisfactory welds can be produced. A contaminated or dirty surface may result in excessive heating at the contact areas and produce defective welds.

(G) *Practical Aspects of Inspection*

Processes also differ in the type of inspection methods which can be used to determine welding quality. Welds that are made by any of the arc processes can readily be

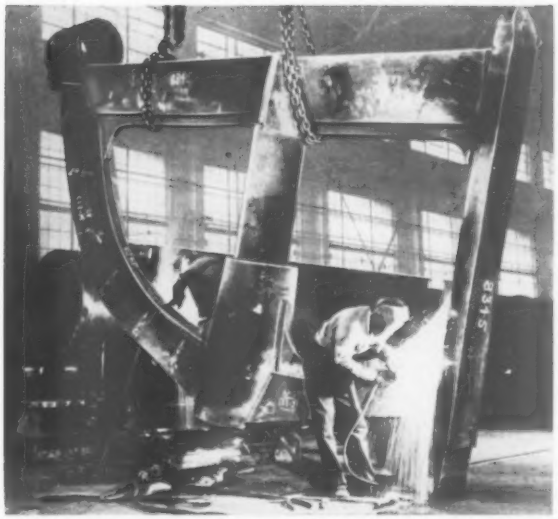

Fig. 6 Large ship stern post being fabricated by the shielded-metal-arc process, using covered electrodes

radiographed and inspected for soundness. Radiographic inspection is not entirely suitable for the inspection of flash welds because the weld is a narrow line. Welds made by some processes can be inspected by magnetic particle examination, while in other welding processes this method cannot be used to evaluate the quality of the weld, such as furnace copper brazed joints.

Processes may also differ according to the portability of the equipment used for welding. In some cases large welding machines which can only be installed in permanent locations can be used, while in other cases the welding equipment is of such portable nature that the welding can be performed in any location.

Examples of some of the commonly known welding processes are shown in the following figures.

Figure 6: Shop welding of large ship stern post, being welded manually by the shielded-metal-arc process, using covered electrodes. It is obvious that the position of welding in the various locations is of special nature. Flash welding of this product would be extremely expensive and impractical. Gas welding or oxy-acetylene welding would be impractical because of the large mass of metal to be welded. Submerged arc welding would not be practical because of the location and the section thickness of the product.

Figure 7 is a photograph of automatic submerged arc welding of girth seams inside a pressure vessel shell.

Figure 8 is an illustration of a large flash welder which is used for the welding of propeller parts.

Fig. 7 Industrial application of the automatic submerged-arc welding process

Figure 9 shows the inert-gas metal-arc welding process using helium and welding deoxidized copper with deoxidized copper filler wire.

III. CHARACTERISTICS OF WELDS MADE BY VARIOUS PROCESSES

Weld quality characteristics related to the various welding processes are:

1. Metallurgical.

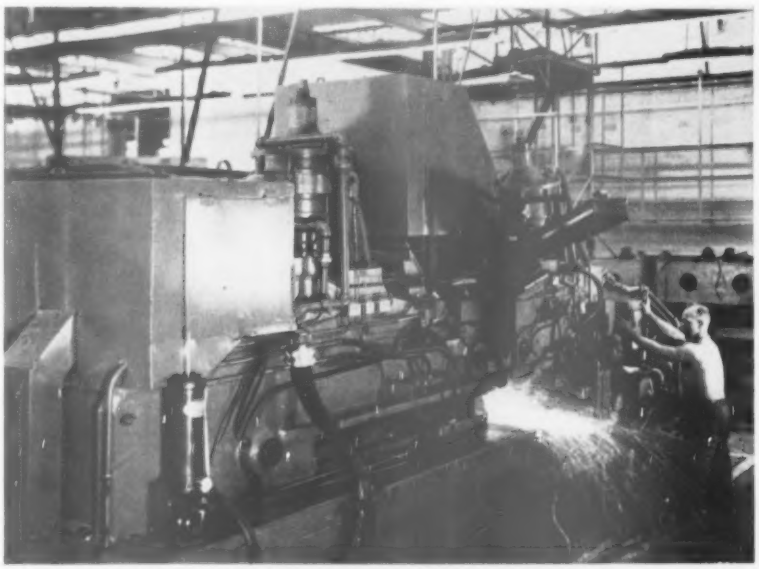

Fig. 8 Flash welder for resistance flash welding of propeller parts

Fig. 9 Application of the inert-gas-shielded metal-arc process, in welding of deoxidized copper

2. Physical.
3. Mechanical.
4. Chemical.
5. Radiographic.
6. Weld geometry.
7. Appearance.
8. Finishing requirements.

(*A*) *Metallurgical*

The metallurgical properties which will be considered are based on macro- and microexamination of cross sections of welds made by different welding processes.

Fig. 10 Macrophotograph of a metal arc weld made by a multiple pass procedure, using covered electrodes (actual size)

Figure 10 is a macrograph of a metal arc weld which is made by a multiple pass procedure using covered electrodes. One of the characteristics of the multipass welding is the multiple heating effect on the metallurgical structure of the previously deposited weld metal. The effect of the heating caused by welding the last layer is to refine or equi-axe the grain structure directly below it, and also to create a distinct heat effect in the parent stock adjacent to the weld. This is shown at higher magnification in Fig. 11. This weld was deposited by manual arc welding, using covered electrodes, and using a multiple of passes for its completion.

Figure 12 is a macrophotograph of an austenitic stainless steel weld which has been deposited in multiple passes, using covered electrodes. The characteris-

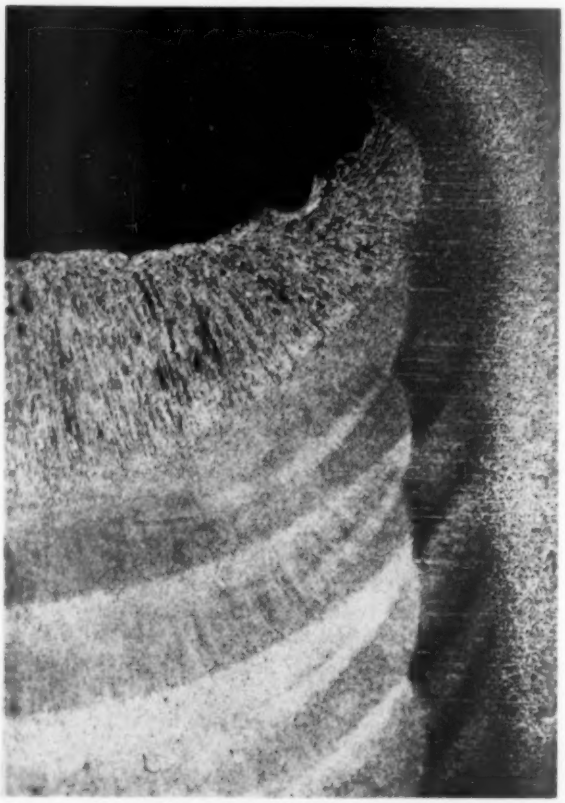

Fig. 11 Macrophotograph of multiple-pass weld metal, showing the heat-affected area adjacent to the weld. Magnified 3 ×

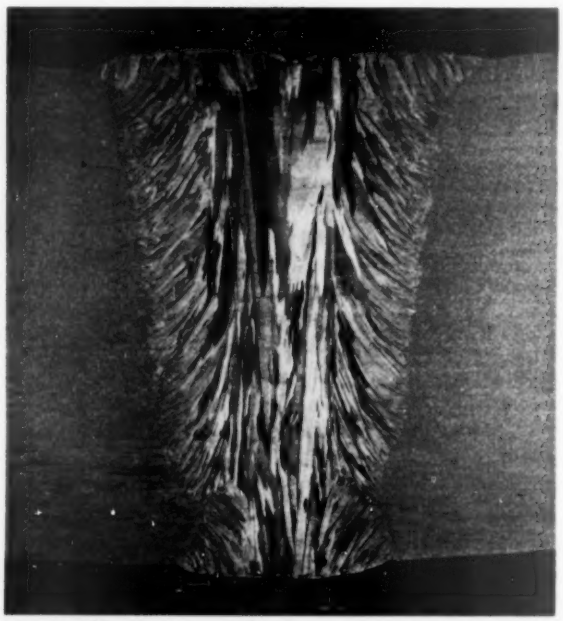

Fig. 12 Macrophotograph of an austenitic type of weld metal which was made by multiple pass deposition. Note continuation of the dendritic structure from layer to layer. Magnified 2 ×

tic columnar structure continues from the first layer to the last layer and no sharp demarcations between the various layers can be observed in the macrograph. This condition is typical in the macro structures of all shielded-metal-arc welding processes. This characteristic is observed in austenitic and ferritic stainless steel multipass welds, as well as in some nonferrous welds.

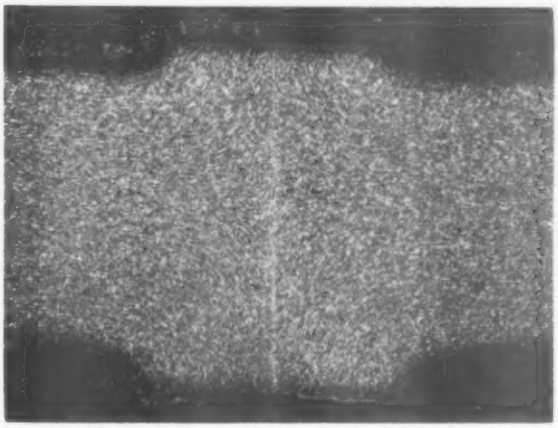

Fig. 13 Macrophotograph of a flash weld made in $^1/_4$-in. carbon steel plate. Magnified 4 ×

Figure 13 is a macrophotograph of a flash weld. This cross section clearly shows that the weld is a line and fusion was obtained by the application of pressure and heat. The extrusion of the metal and grain flow of the parent stock adjacent to the weld line is clearly shown. The weld in the flash weld consists of merely a line. The effect of the grain flow in the weld area caused by the upsetting operation is such that the mechanical properties of the weld approach the transverse properties of the parent stock.

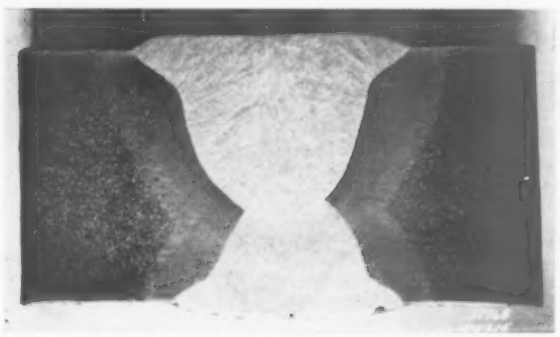

Fig. 14 Macrophotograph of a two-pass weld in ASTM A-285 steel made by the submerged-arc welding process

Figure 14 is a macrophotograph of a two-pass weld in 1 $^1/_4$-in. ASTM A285 steel, made by the submerged-arc welding process, using carbon steel filler wire. This macrostructure is typical of submerged arc welding in single-pass thick layers. Cross section of the weld reveals a coarse columnar structure. The mechanical properties of such a weld are not greatly influenced by the columnar structure, since there is adequate ductility and strength with this type of structure.

Figure 15 is a photograph of a copper-brazed control

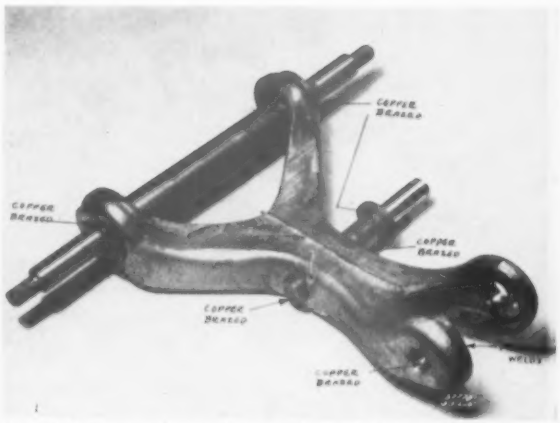

Fig. 15 Copper-brazed control arm fabricated by copper brazing, flash welding and projection welding

arm. The brazing was performed in a continuous conveyor belt brazing furnace. The brazing was completed at a temperature of 2050° F and the atmosphere in the furnace was cracked butane gas. The brazing is accomplished by capillary action in which the copper wets the metal surfaces that are adjoining the parts together and fills the joints between the abutting edges.

Figure 16 is a macrophotograph of a copper-brazed joint of the control arm shown in Fig. 15. The cross section reveals the copper penetration which was the result of capillary action at the tightly fitting sections.

Figure 17 is a photomicrograph, at 100 diam magnification, of a copper-brazed joint which clearly shows the film of copper joining two carbon steel sections.

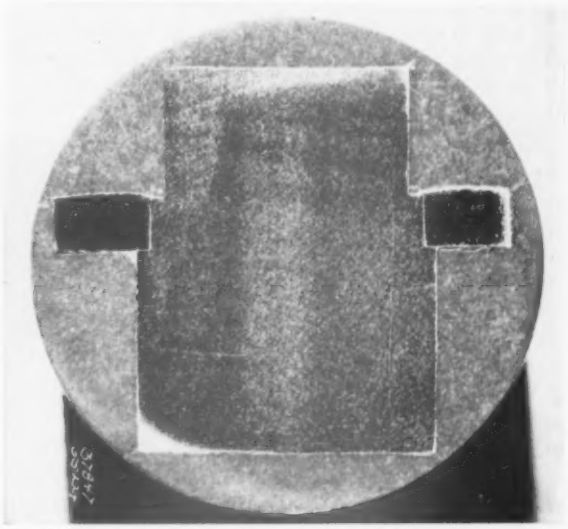

Fig. 16 A cross section through one of the copper-brazed joints indicated in Fig. 15

Figure 18 is a chart showing the relationship between the strength of the brazed joint versus the thickness or gap of the joint to be brazed. It may be noted that the maximum strength is obtained where a fit approximately 0.0015 in. is used between the abutting surface of the metal. As the gap is increased or decreased, the strength varies, as shown.

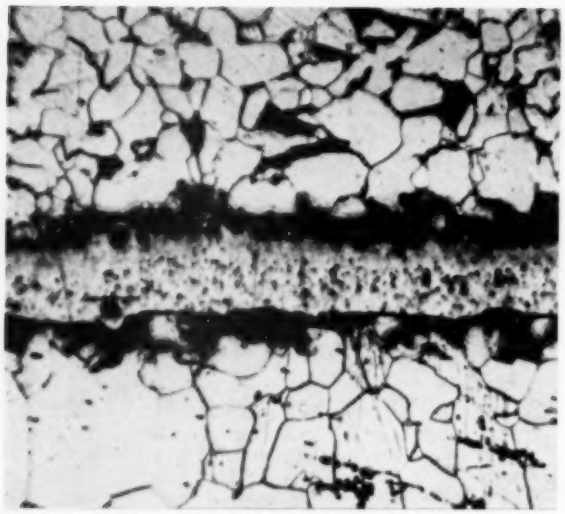

Fig. 17 A photomicrograph of the copper-brazed area which shows the copper retained between the sections. Magnified 100 ×

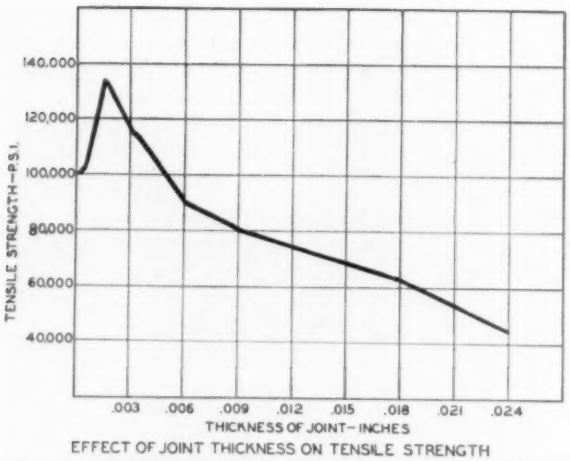

Fig. 18 Relationship between strength of a brazed joint and the thickness or gap between parts to be brazed

Figure 19 is a macrophotograph of a spot weld showing a typical nugget in the spot-welded area. The material is austenitic stainless Type 304 of approximately 0.050 in. thickness.

Figure 20 is a macrophotograph of a thermit weld which was made in a 10-in. shaft of SAE 1040 steel and welded with a standard thermit mixture. The typical thermit type of weld in which the hot metal melts or washes the top and bottom corners of the section is clearly shown.

Figure 21 is a macrophotograph of an inert-gas metal-arc weld in deoxidized copper, using tin bearing copper filler metal. These macros reveal the coarse structure of the weld metal and also the refined grain structure of the top layer of the weld after peening, and the subsequent welding of the bottom layer. The upper specimen shows the effect of welding the bottom pass upon the peened top layer, in which the top layer weld metal is recrystallized as fine equi-axed grains. The lower specimen is of the same weld after stress relieving or annealing at 1000° F, and shows but slight further refinement of the top peened weld metal.

(B) *Physical and Mechanical Properties of the Welds*

The physical and mechanical properties of welds may vary according to the welding process which is used. As shown in Fig. 13 the characteristic structure of a flash weld reveals an out bent fiber condition and the mechanical properties of the weld are similar to the transverse mechanical properties of the parent material. In welds made by any of the arc-welding processes, the physical and mechanical properties of the weld can vary widely according to the composition of

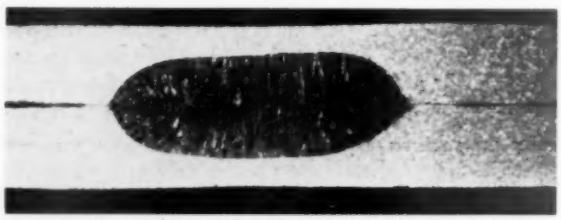

Fig. 19 Macrophotograph of a spot weld made between 0.050-in. thick Type 304 stainless steel sheets, showing weld nugget. Magnified approximately 10 ×

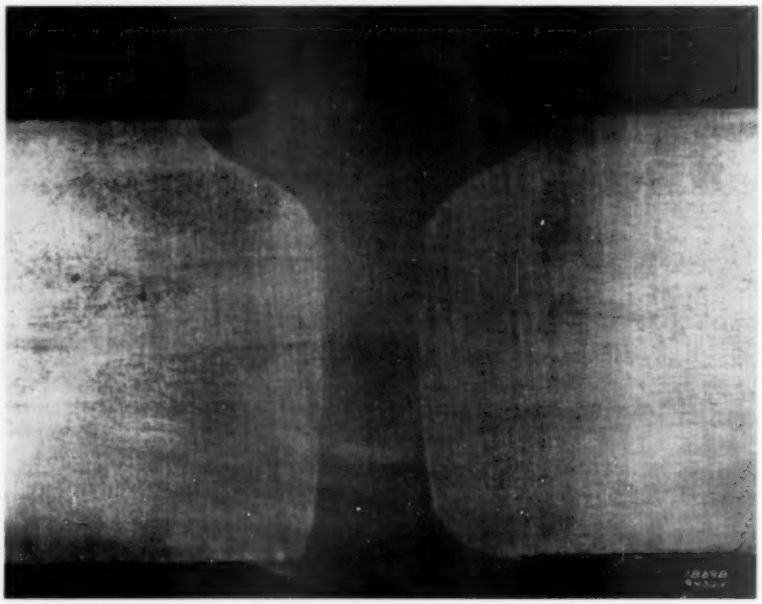

Fig. 20 Macrograph of a thermit weld made in 10-in. shaft of SAE 1040 steel (approximately half size)

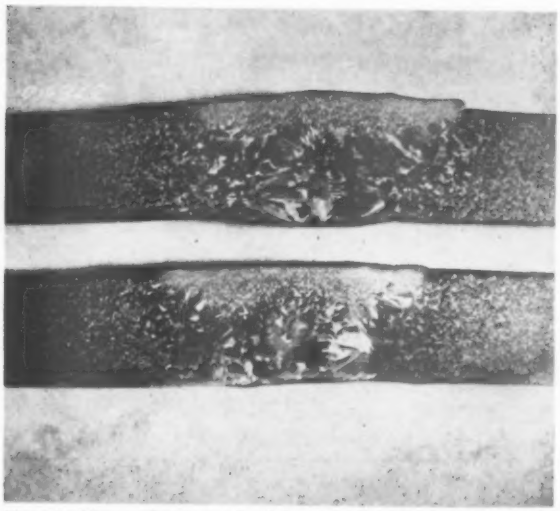

Fig. 21 Macrophotograph of deoxidized copper welds made by the inert-gas-shielded metal-arc process, using tin bearing copper filler metal (actual size)

the weld metal, which is governed by the composition of the filler metal. In the resistance-welding processes, the physical and mechanical properties of the weld joint are governed by the properties of the parent metal and cannot be varied by chemical composition, since no filler metal is added and the composition of the welded joint is substantially the same as the parent stock.

In the arc-welding, gas-welding, brazing and thermit-welding processes, the mechanical properties and the physical properties of the weld are influenced directly or widely by the composition of the filler metal that is added to the weld and by the dilution with the parent stock. Consideration must therefore be given to the composition of the filler metal and to the degree of dilution in determining the mechanical properties which will be obtained in these processes.

The physical and mechanical properties of the weld metal can be altered by heat treatment following the welding operation.

(C) *Chemical Properties*

The chemical composition of a weld depends to a large extent on the chemical composition of the filler metal, if used, and the degree of dilution with the parent metal. Weld metal chemical composition can vary within large limits in those processes where filler metal additions are used, such as in the arc-welding, gas-welding, brazing and thermit-welding processes.

The composition of welds made by the resistance-welding processes cannot be altered unless dissimilar metals are joined together, and the composition of the resultant dissimilar metal may vary according to the chemistry of the component parts.

(D) *Radiographic*

The radiographic quality of the welds made by the various processes may vary according to the process used. It is well known that the bare wire metal arc welds contain excessive amounts of fine porosity. Filler wire compositions and electrode coating compositions also affect the quality of shielded-metal-arc welds. Flux inclusions and porosity sometimes are found in the welds made by the torch brazing processes.

(E) *Weld Geometry*

The weld geometry, i.e., the form or shape of the weld, depends upon the joint design and the welding process used. The geometry of a weld made by the shielded-metal arc process may consist of a symmetrical weld according to the design of the welding groove. Butt welds are used with the arc-welding process—the weld is a continuation of the parent plate. In a resistance spot weld the geometry of the weld is usually in the form of a nugget joining two separate sections. This is shown in Fig. 19. The geometry of flash welds is entirely different than any other welds and is in the form of a line. See Fig. 13.

The geometry of a copper-brazed weld joint differs from others in that it consists of a thin copper weld line, joining the parts together.

(F) *Appearance*

The outward surface appearance of welds made by the various welding processes differs to a large extent from process to process. The surface appearance of welds made by the inert-gas metal-arc process in some metals is clean, bright, and free from oxides, indicating complete shielding from the atmosphere.

The appearance of a flash weld is characteristic of the flash welding process, in which the extruded metal is rough and irregular and in most applications is removed for appearance or inspection reasons.

Submerged arc welds generally can be identified by a very smooth surface appearance.

Welds made by covered electrodes in the shielded-metal-arc process can usually be identified by the characteristic surface appearance, as indicated by the ripples on the surface and slag indentations.

(G) *Finishing Requirements*

The processes differ markedly in the finish requirements that are specified. Flash welds are extremely rough, with the extruded metal presenting an unsightly appearance. In most cases the excess weld is trimmed off to present a uniform weld section.

Other welds do not require finishing other than a wire brushing or the removal of slag which covers the weld surface. Some welds, such as those made by the resistance-welding processes, such as spot welds, do not require any finishing operations.

Table 1—Recommended Processes for Welding Metals and Alloys

Welding process	*Low-carbon Mild steel; Types SAE 1010, SAE 1020*	*Medium-carbon steel; Types SAE 1030, SAE 1050*	*Wrought-alloy eng. steels; Types SAE 4130, SAE 4340*	*High-alloy stainless steels, austenitic; Types AISI 301-309-316*	*Stainless steels, ferritic and martensitic; Types AISI 405-430*	*High-temperature alloys; 19-9DL, 16-25-6*	*Cast iron, gray iron*
Shielded-metal-arc (coated electrode)	R	R	R	R	R	R	S
Submerged-arc	R	R	R	R	S	S	NR
Atomic hydrogen	S	S	S	R	S	S	NR
Inert-gas tungsten-arc	S	S	S	R	S	S	S
Inert-gas metal-arc	S	S	S	R	S	S	NR
Flash welding	R	R	R	R	S	S	NR
Spot welding	R	R	R	R	S	S	NA
Gas welding (oxy-acetylene)	R	R	S	S	S	S	R
Brazing-furnace	R	R	S	RS	S	NR	NR
Brazing-torch	S	S	NR	S	S	NR	R
Thermit	S	S	S	NR	NR	NR	S

R = recommended, S = satisfactory, NR = not recommended, NA = not applicable.

Table 2—Recommended Processes for Welding Metals and Alloys

Welding process	*Aluminum and aluminum alloys*	*Nickel and nickel alloys*	*Copper and copper alloys*	*Magnesium and magnesium alloys*	*Precious metals* — *Silver*	*Precious metals* — *Gold, platinum, iridium*	*Rare metals* — *Titanium and titanium alloys*	*Rare metals* — *Uranium, molybdenum, vanadium, zirconium, tungsten*
Shielded-metal-arc (coated electrode)	S	R	NR	NA	NR	NR	NA	NA
Submerged-arc	NR	S	NR	NA	NR	NR	NA	NA
Atomic hydrogen	S	S	NR	NR	R	R	NA	NR
Inert-gas tungsten-arc	R	R	R	R	R	R	R	R
Inert-gas metal-arc	R	R	R	S	S	S	S	S*
Flash welding	S	S	S	NR	S	S	S	S
Spot welding	R	R	S	S	NR	S	S	S
Gas welding (oxy-acetylene)	S	S	S	NR	R	R	NA	NR
Brazing-furnace	R	S	S	NR	S	S	NR	NR
Brazing-torch	R	R	R	NR	R	R	NR	NR
Thermit	NA	NR	NR	NA	NR	NR	NA	NR

S = satisfactory, R = recommended, NR = not recommended, NA = not applicable.
*S Questionable

IV. COMPOSITION OF METALS TO BE WELDED

The fourth factor to be considered in the selection of welding processes is the composition of the metals to be welded. The composition of the metals to be welded largely governs the selection of the welding process that is applicable for the particular metal. Some metals like carbon steels can be welded by most of the known welding processes. Other metals and alloys of special composition can only be welded by a few of the processes.

Recommendations as to the type of processes which are most generally used are shown in Tables 1 and 2. These recommendations are based on general applications and do not apply to special cases, or where special factors are to be considered.

Titanium and titanium alloys can only be welded at the present time with the inert-gas-tungsten arc, inert-gas metal-arc and a few of the resistance-welding processes.

V. WELDING JOINT DESIGN

Another factor which is of importance in the selection of the most suitable welding process is the welding joint design. For most welding designs there are four basic joint types, as shown in Fig. 22. These joint types are commonly used in most of the welding processes. These are butt joints, lap joints, fillet joints, edge joints and overlay welding. Other special types of joints which are commonly used are projection joints, percussion joints and brazed joints, as shown in Fig. 23.

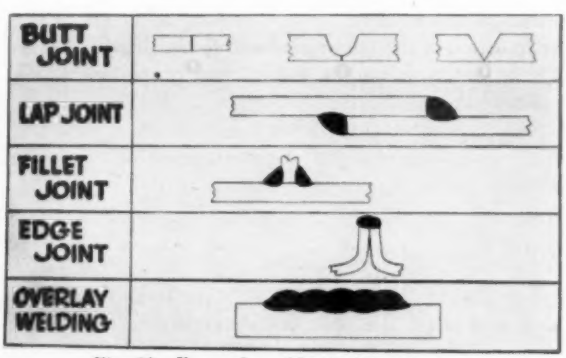

Fig. 22 Examples of basic joint designs

These basic joint designs can only be used with certain welding processes. For example, a lap joint cannot be used for flash welding, or a fillet type of weld can-

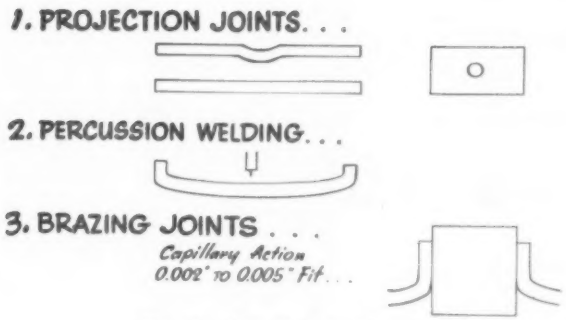

Fig. 23 Special joint designs

not be made by resistance welding. The recommended processes for various joint designs are shown in Table 3. This table shows which basic joint designs are applicable to the various processes and thicknesses of material.

VI. PRODUCTION RATE

A factor which is of importance in the selection of the proper welding process is the rate of production. If welded units are made at the rate of 1000 per hour or one per hour, or one per day or per year, the production rate has an important bearing on the selection of the most economical welding process. For most applications the resistance-welding processes where applicable offer the greatest economy when the production rate justifies the cost of the welding equipment.

Flash-welding equipment machines may cost from a few thousand to a million dollars, and unless the production rate is high, the cost per unit cannot be justified. Many products may require a redesign if the production rate is sufficiently high to justify lower cost of welding by adaptation of special automatic welding processes.

VII. POWER AVAILABILITY

The power supply has a bearing on the selection of the welding process, since with certain welding processes an adequate amount of electrical power supply must be available. Where electric power is not available, portable power generating units can be employed, or welding processes used which do not depend on electric power.

VIII. ECONOMICS OF THE PROCESS

This factor is of greatest importance in the selection of the most suitable welding process, since the basis of selection is for the economical process or method of welding, producing a product that will fulfill the service requirements adequately. The cost of a welding process will depend upon the following factors:

1. Preparation costs.
2. Set-up operation costs.
3. Direct welding costs.
4. Equipment costs.
5. Finishing costs.

With present inflationary trends and with high labor costs, it is of utmost importance to select welding processes which can be made with the minimum amount of labor, or if possible substitute automatic welding operations which will require little or no training of the welding operators. Some welding processes that can be selected may be the most economical from the standpoint of lowest labor costs, but may result in higher material cost, and lower total welding cost per unit.

1. Preparation Costs

Under this heading is included the cost of preparing for welding, such as scarfing and surface preparation of the parts prior to welding. The cost of shearing or gas cutting may also be included in preparation costs. In the resistance welding processes it is usually necessary to prepare the surface by removing scale and other for-

Table 3—Recommended Processes Based on Joint Design

	BUTT JOINT		LAP JOINT		FILLET JOINT		EDGE JOINT		
Welding process	*Light section**	*Heavy section†*	*Light section*	*Heavy section*	*Light section*	*Heavy section*	*Light section*	*Heavy section*	*Overlay welding*
Shielded-metal-arc (coated electrode)	S	R	R	R	R	R	NR	R	R
Submerged-arc	S	R	S	R	S	R	NR	S	R
Atomic hydrogen	R	S	S	S	S	R	R	S	R
Inert-gas tungsten-arc	R	S	R	S	R	S	R	S	R
Inert-gas metal-arc	NR	R	NR	R	NR	R	NR	S	R
Flash welding	NR	R	NA	NA	NA	NR	NA	NA	NA
Spot welding	NA	NA	R	R	NA	NA	NA	NA	NA
Seam welding	NA	NA	R	R	NA	NA	R	R	NA
Gas welding (oxy-acetylene)	R	S	R	S	R	S	R	S	R
Brazing-furnace	NR	NR	R	R	R	R	NA	NA	NR
Brazing-torch	S	S	R	R	R	R	S	S	S
Thermit	NA	R	NA	NA	NA	NA	NA	NA	NR

* Light section: 0.005–0.125 in.
† Heavy section: 1/8 in. and over.
R = recommended, S = satisfactory, NR = not recommended, NA = not applicable.

eign material from the surface to be welded in order to have a uniform condition for resistance welding.

2. *Set-Up Operation Costs*

Under this heading we include the cost required for assembling into the welding fixture, the welding of holding lugs to position the parts properly, moving of welding fixtures to the welding equipment, the procurement of welding supplies and preheating for welding.

3. *Direct Welding Costs*

Under this item are included the cost of labor, material and power or heat energy for welding.

Labor will include the direct labor charges accumulated in welding operations, the material to be welded, and all items required for welding such as electric power, gases, fluxes, covered electrodes, filler wire, etc.

4. *Equipment Costs*

Under this factor we must include the depreciation and interest on capital investment on the welding equipment used. For many processes such as the manual arc welding where the investment cost will be in the neighborhood of $1000 or less, the depreciation and interest on capital investment is almost a negligible figure. On the other hand, resistance welding machines such as flash welders, may cost a half million dollars and the depreciation and interest on such a capital investment becomes of importance and must be considered in the cost of the welding process. Under equipment one must also consider costs of maintaining equipment and the replacements of worn parts.

5. *Finishing Costs*

Under this factor we must consider the cost of removal of excess weld metal and surface finishing such as grinding, polishing and sandblasting, removal of welding lugs, heat treatment after welding, including stress relieving or heat treatment to obtain certain mechanical properties in the welded joint. Under finishing costs also should be included the cost of inspection. This may consist of radiographic or magnetic particle inspection, or some of the nondestructive methods such as supersonic or oil penetrant inspection methods. In other cases where parts are destroyed in the course of inspection, the cost of the loss of such parts must be included in the finishing costs.

Figure 24 shows the relative cost per unit including material, labor, power and equipment costs for five different welding processes. It will be noted that for some of the processes, namely, the covered electrode, the labor cost is probably the largest factor in the unit cost of welding. In submerged arc welding, material cost is the largest factor in this comparison. In inert-gas-metal arc welding the cost of material is the highest single factor. In flash welding, equipment cost is the largest factor. In thermit welding the labor and material costs are the large items in the distribution of welding costs.

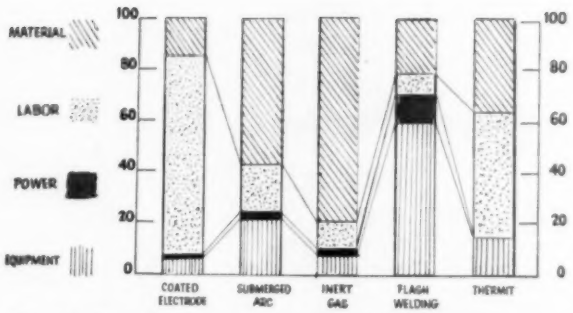

Fig. 24 Comparative cost per unit with reference to material, labor, power and equipment for five different welding processes

The distribution of welding costs per unit is only for comparison purposes to illustrate the relation of labor, material, power and equipment costs. The distribution chart for the types of welding processes shown indicates that the cost of material, labor, power and equipment varies widely with the different processes.

SUMMARY

In reviewing the various factors which should be considered in the selection of the most suitable welding process, it is important to first give consideration to the service requirements and engineering design and then to evaluate the various factors discussed, and to select a design for the particular process which will result in the most economical welding cost. This method can be applied generally to a new product, where freedom as to design and selection of material is possible. Where a product has already been designed and it is necessary to re-evaluate the welding process for the lowest welding cost, the selection of the welding process is somewhat limited and in that case must be based upon the processes which are most adaptable and result in the lowest possible cost.

One of the important factors to be considered in the selection of the welding process is that the design must be such to permit economical fabrication by welding. In the past, welding engineers and design engineers have not given sufficient thought to redesign for the most economical process. The possibilities for further reduction in welding costs in the future will depend to a large extent on the redesign of welded products, in order that the most economical process can be selected. Further research investigations will undoubtedly result in improvement in the present welding processes and may stimulate new inventions for more economical welding process.

Cone Arc Welding

A new automatic and semiautomatic inert-gas-shielded arc-welding process has been developed for welding a multitude of thin-walled small diameter tubes in a single header

by P. Patriarca and G. M. Slaughter

Abstract

A new inert-gas-shielded semiautomatic arc-welding process known as the Cone Arc Process is described and evaluated by experiment. The process utilizes standard welding equipment and is applicable to the reliable fabrication of miniature tube-to-header type heat exchangers. Experiments were conducted using small diameter, thin-walled stainless steel tubing with header sheets of sufficient thickness to insure the production of consistently good welds. An investigation of the effects of arc current and welding time indicated that these variables were not critical and that precise control of their magnitude was not necessary within liberal limits. After determination of proper welding conditions, weld penetrations of twice the tube wall thickness could be obtained without excessive constriction of the internal diameter of the tube. A hole-to-hole distance, center to center, of twice the outside diameter of the tube was found to be desirable in preventing the overlap of fusion zones.

INTRODUCTION

IN RECENT years there has been a growing interest in the application of miniature heat exchangers of the tube-to-header type design for elevated temperature service in the presence of cooling media constituting a severe corrosive environment.

The fabrication of an assembly consisting of a multitude of thin-walled, small-diameter tubes, welded into a single header by conventional welding techniques, has proved to be extremely difficult, if not impossible, to accomplish with consistency and reliability, thereby requiring the development of a new and yet relatively simple automatic or semiautomatic welding process.

Initial experiments with an inert-gas-shielded arc-welding process, suggested by previous investigators,[1] showed considerable promise in the welding of small tubes to headers. In this process, now known as the Cone Arc Process, it has been postulated that the arc rotates around the header hole at high speeds, distributing uniformly the energy required to make a peripheral weld of a tube into a header sheet.

Although the phase of the investigation described herein was preliminary and limited in scope, it is nevertheless presented in the belief that it may suggest applications to industries seeking a reliable means of fabrication of miniature heat exchangers incorporating the welded tube-to-header design.

OBJECT AND SCOPE

This study, undertaken by the Welding Section of the Metallurgy Division of Oak Ridge National Laboratory, was initiated to determine the limitations and the range of application of the Cone Arc Process.

Fig. 1 Photograph of apparatus used for Cone Arc welding

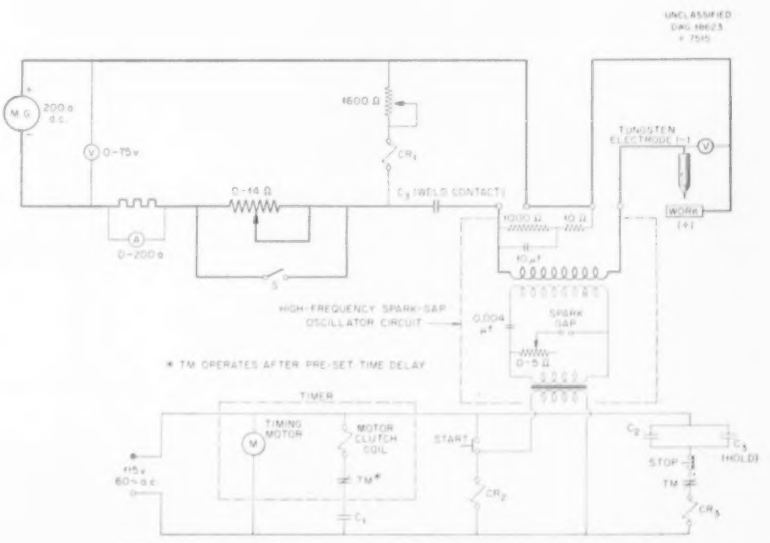

Fig. 2 Schematic diagram of Cone Arc welding circuit

P. Patriarca and **G. M. Slaughter** are Metallurgists with the Oak Ridge National Laboratory, operated by Carbide & Carbon Chemicals Co., a division of Union Carbide & Carbon Corp., Oak Ridge, Tenn.

MATERIAL

The material used in this investigation consisted of type 316 stainless steel tubing 0.100 in. OD, 0.010-in. wall and type 316 stainless steel sheet 0.125 in. thick from which experimental headers were machined.

WELDING EQUIPMENT

Apparatus suitable for Cone Arc welding was assembled for the most part from commercially available equipment. A photograph of the components of the apparatus is presented in Fig. 1. A schematic diagram of the circuit used is presented in Fig. 2.

1. A 200-amp direct-current welding generator was used as the welding power supply and was supplemented with an adjustable series resistor which permitted obtaining a stable arc at a current level as low as 5 amp.

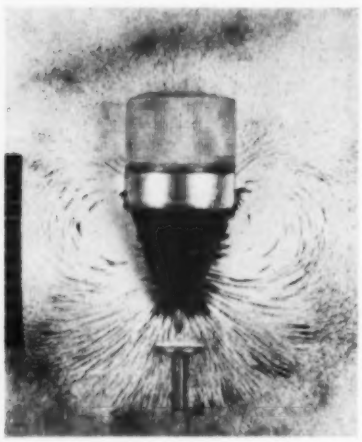

Fig. 3 Photograph of an iron filing magnetic field pattern of the Alnico permanent magnet nozzle required for Cone Arc welding

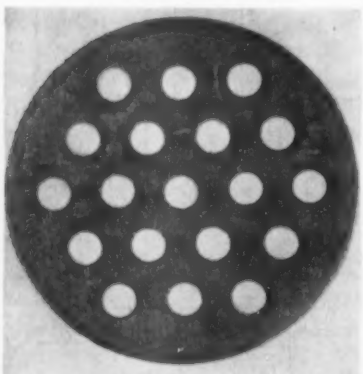

Fig. 4 Photograph of a header of the design used in this investigation. Mag. 2.5 ×

2. The high frequency required for reliable starting of the inert arc was provided by a spark gap oscillator and was used in conjunction with thoriated tungsten electrodes.

3. The commercially available timing circuit used to time the duration of arc current was found to be reproducible within 0.05 sec with arc times of 0.5 sec or over.

4. A welding contactor was incorporated into a control circuit, the operation of which, with reference to Fig. 2, was briefly as follows:

Upon starting the welding generator, the open-circuit voltage of from 50 to 70 v energizes relay CR_1 and operates contact C_1, permitting the timer circuit to reset. When the welding operator momentarily depresses the start button, weld contact C_3 closes, and the high-frequency oscillator is energized to assist in starting the welding arc. At the instant that the open-circuit voltage drops to arc voltage, the contact C_1 or relay CR_1 opens, allowing the timer to begin timing. At the end of the preset timing period, the contact TM opens, thereby de-energizing relay CR_2, thus opening the weld contactor C_2 and breaking the Cone Arc welding arc. This arrangement enables accurate control of arc current duration, independent of any relay in the arc striking by the high-frequency pilot.

5. A commercially available machine holder provided with an Alnico permanent magnet nozzle was used as the welding torch and may be considered as the fundamental requirement for the Cone Arc Process.

Figure 3 is a photograph of an iron filing pattern of the magnetic lines of flux of the Alnico permanent magnet used in this investigation. The portion of the nozzle directly above the stainless steel tube and header work is of soft iron and serves to concentrate lines of flux roughly parallel to the axis of the welding electrode. The Alnico permanent magnet is directly above the soft iron, the remainder of the nozzle being of aluminum and plastic.

It has been proposed that the operation of a Cone Arc is dependent on the establishment of an arc stream which cuts the lines of flux at a small angle. Since the welding arc originates at the cathode spot at the tip of the pointed thoriated tungsten electrode centered above the tube, and must impinge on a point on the periphery of the header hole to complete the welding circuit, this requirement is realized.

The arc current under these conditions cuts lines of force in the magnetic field, and it has been postulated that a force tangential to the tube periphery results, active in the plane of the header sheet. These forces are said to result in the rotation of the initial arc beam around the header hole at very high speeds, thereby distributing the energy required to make a uniform peripheral weld of a tube into a header sheet.

INSTRUMENTATION

Instrumentation found satisfactory for reproducible results consisted of means for the measurement of the arc voltage, arc current and the duration of the welding current. A six-channel, film type recording oscillograph was employed initially for this purpose since the arc times used in this investigation were generally shorter than the speed of response of indicating-type panel instruments. Subsequent experiments indicated that panel meters, calibrated against oscillographic traces to correct for the slow speed of response, could be used satisfactorily to check the duplication of established welding conditions.

The graphic ammeter and voltmeter, shown in Fig. 1, were not used in this investigation. These instruments were originally built into the equipment as illustrated, since the same power supply is used on other research projects involving conventional machine inert-gas-shielded arc-welding methods.

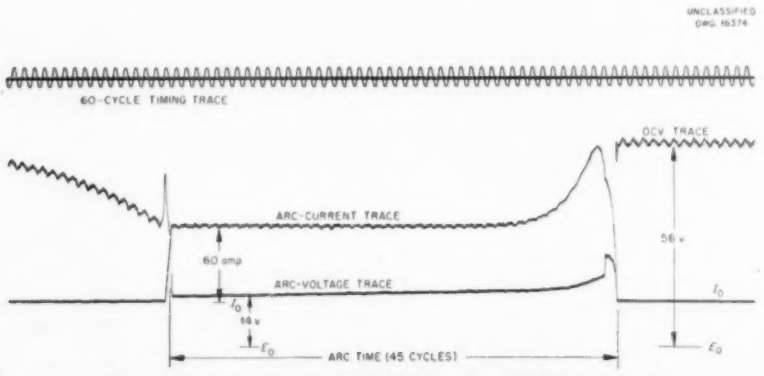

Fig. 5 Photograph of a typical Cone Arc weld oscillograph

EXPERIMENTAL PROCEDURE

The variables associated with Cone Arc welding which received attention during this investigation were as follows:

1. Arc current magnitude.
2. Arc current duration.
3. Arc length.
4. Inert-gas shield.
5. Work geometry (header and tubing configuration).

It was recognized at the onset of the study that the uniformity of heat transfer during welding was a very important variable. Since the header geometry, header size and tubing size would affect the behavior of the heat flow pattern away from the weld pool and, hence, the uniformity of the finished weld, experiments were conducted using a single tube-to-header geometry.

Circular headers, 1.10 in. in diameter were fabricated from type 316 stainless steel sheet, 0.125 in. thick. Nineteen 0.100-in. diameter holes were drilled to receive type 316 stainless steel tubes, 0.100 in. OD, 0.010-in. wall and 3 in. long. The basic header pattern was an equilateral triangle with a header hole drilled at each apex. This geometry resulted in a minimum of 0.100 in. between adjacent tubes, or between a tube wall and the edge of the header. This header geometry is illustrated in Fig. 4, a photograph of a header, machined as described above.

The effect of arc current magnitude was determined by varying arc current over a range of from 40 to 85 amp with an arc time of 1.5 sec and an arc length of 0.050 in. The effect of arc current duration was determined by varying the arc time through a range of from 1 to 5 sec. while maintaining the arc current at 59 amp, direct current with an arc distance of 0.050 in.

The effect of arc length was investigated by determining the conditions required for obtaining 19 consistent and uniform welds at each of two arc distances of 0.050 and 0.100 in., measured as the perpendicular distance from the tip of the tungsten electrode to the plane surface of the header sheet.

The electrode, 0.0625 in. in diameter, was lowered into the 0.080 in. ID of each tube, and centered by eye to a reproducible accuracy of ±0.002 in. The chosen arc length was reproduced by referring to a magnified scale mounted on the electrode holder, reading in 0.001 in. increments. Industrially, centering of work could be readily accomplished by an indexing mechanism.

Initial experiments indicated that an argon gas shield provided excellent arc stability during the short welding times required for Cone Arc welding; whereas, with helium, the arc proved to be somewhat erratic and extremely difficult to start with high frequency at the open-

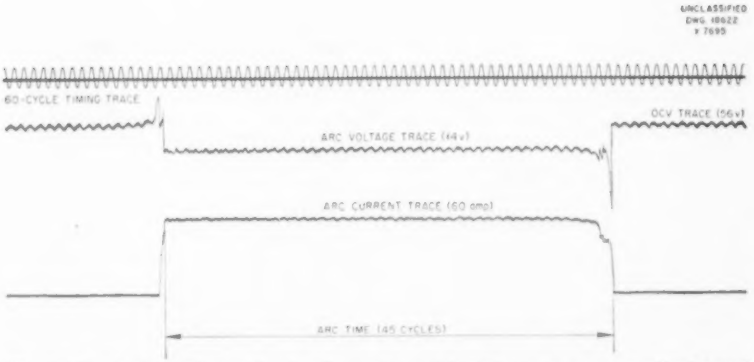

Fig. 6 Typical oscillograph of a Cone Arc weld with surge current eliminated

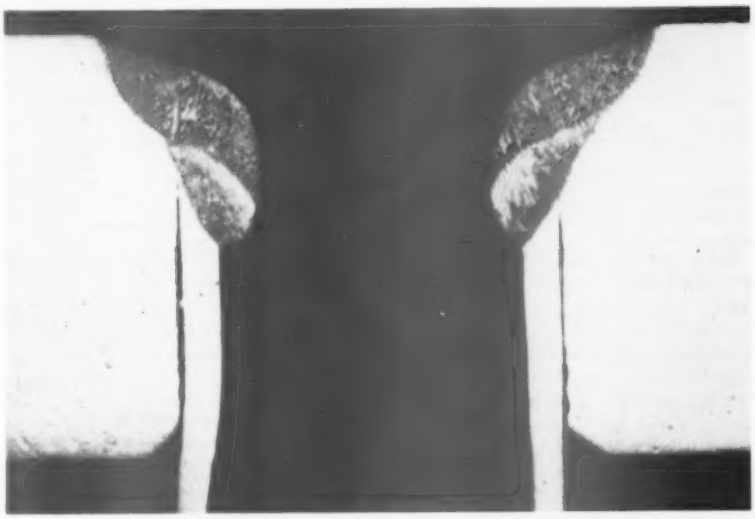

Fig. 7 Photomacrograph of a typical Cone Arc weld. Mag. 20 ×. Etch G. Regia

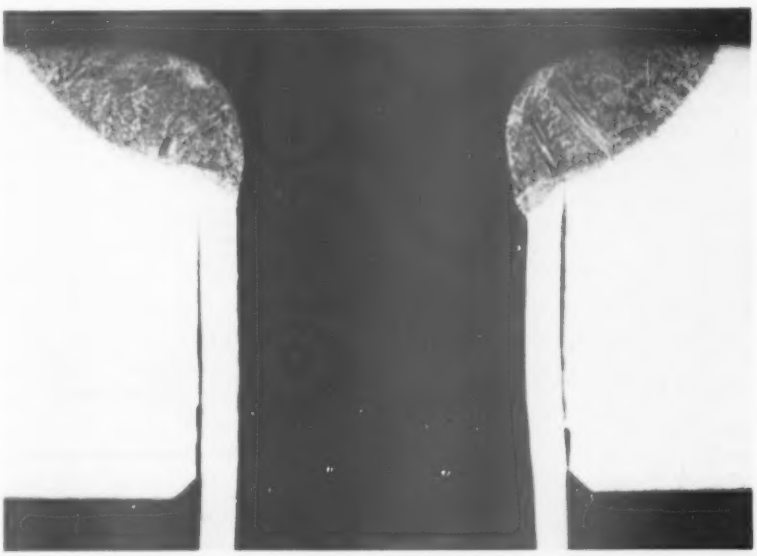

Fig. 8 Photomacrograph of a typical Cone Arc weld with the tube recessed 0.020 in. below the header surface prior to welding. Mag. 20 ×. Etch G. Regia

circuit voltages available. Experiments were conducted to determine the argon flow rate required to insure a clean, bright weld at all times. As a result of these experiments, an argon gas flow of 30 cfh was used throughout this investigation.

Complete header samples consisting of 19 tube-to-header joints were welded with each set of welding conditions considered to be close to optimum in order to evaluate the consistency of the welds.

RESULTS

Figure 5 shows a typical Cone Arc weld oscillograph illustrating the instantaneous behavior of arc current and arc voltage as a function of time. Referring to Fig. 5, reading from right to left, it may be seen that the arc current exhibits an initial surge value approximately double the steady state arc current, and then decays exponentially to the steady state value in approximately $^1/_5$ sec.

The addition of 0.5 ohm of series resistance to the welding circuit effectively eliminated the surge current, as evidenced by the current trace appearing in the oscillograph of Fig. 6.

Cone Arc welds were made using the modified circuit in order to compare the results with those obtained with a surge current present. Metallographic examination of these welds indicated that the presence of a surge current was not deleterious within the limits of this investigation since no significant differences between welds were evident. A photomacrograph of a typical Cone Arc weld is shown in Fig. 7. This weld was made with 60 amp of d-c current maintained for 1.5 sec. The arc distance was 0.050 in. and the tube was initially set flush with the header surface before welding.

Examination of Fig. 7 will reveal that a typical Cone Arc weld could be described metallographically and dimensionally by three parameters, D_I, D_0 and P, as defined below:

D_I, the average minimum diameter of the tube hole after welding, was measured with a microscope.

D_0, the average maximum diameter of the weld pool, extending outward from the tube onto the header sheet, was measured as above. Both D_I and D_0 could be determined without sectioning, by viewing the weld from above.

P, the penetration, was taken as the minimum perpendicular distance between the unwelded root of the weld to the surface of the weld. The penetration, P, was measured microscopically after the weld had been prepared for metallographic examination by polishing a section along the diameter of the tube.

It may be noted that the weld of Fig. 7 exhibits a D_I of approximately 75% of the original inside diameter of the tube. The lower, lighter-etching portion of the constriction may be attributed to the melting down of the tube, initially inserted flush with the header sheet. As the tube periphery melted away, further heating was concentrated on the header periphery resulting in the upper, darker-etching portion of the fusion zone. Verification of this explanation was provided by examination of Cone Arc welds of tubes recessed into the header 0.020 in. from the header surface. The weld illustrated in Fig. 8 was made using conditions identical with those of the weld of Fig. 7, with the exception of the recessed tube. It may be noted that the dimensions D_I and D_0 are both noticeably greater since the majority of the initial heat input was concentrated on the header material. Since the recession of a multitude of tubes in a header would provide a more difficult assembly problem in a practical tube-to-header heat exchanger, all other experiments were conducted using tubes inserted flush with the header surface.

The effect of arc current is presented in the graph of Fig. 9. D_0, D_I and P are plotted as a function of arc current magnitude with the other welding variables held constant, as summarized at the top of the figures. Examination of these curves will reveal that about 53.5 amp were required before a complete peripheral weld was achieved.

Visual observation during the production of Cone Arc welds revealed the initial formation of a small crescent-shaped weld pool at any random point on the header periphery which very rapidly grew circumferentially into a continuous pool unless the current was too low, or the time too short.

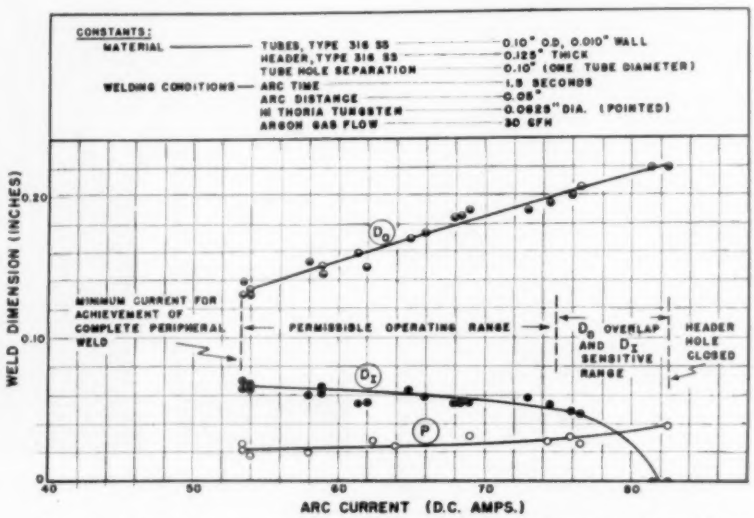

Fig. 9 Effect of arc current on Cone Arc weld parameters D_0, D_I and P

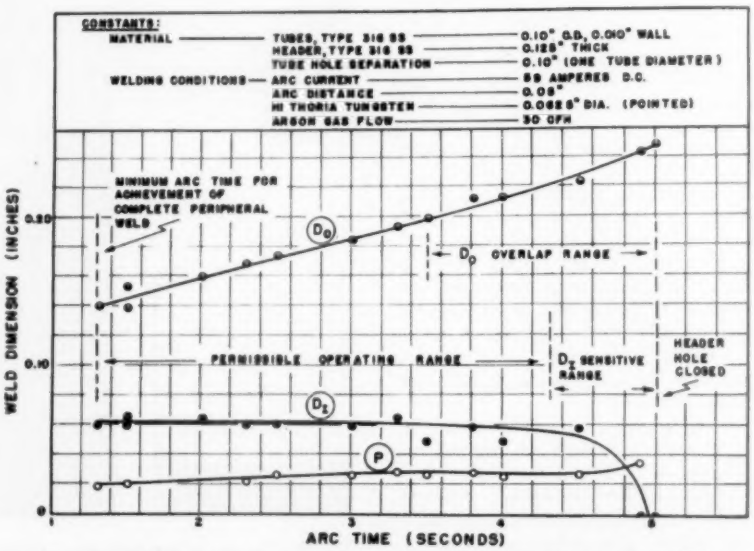

Fig. 10 Effect of arc time on Cone Arc weld parameters D_0, D_I and P

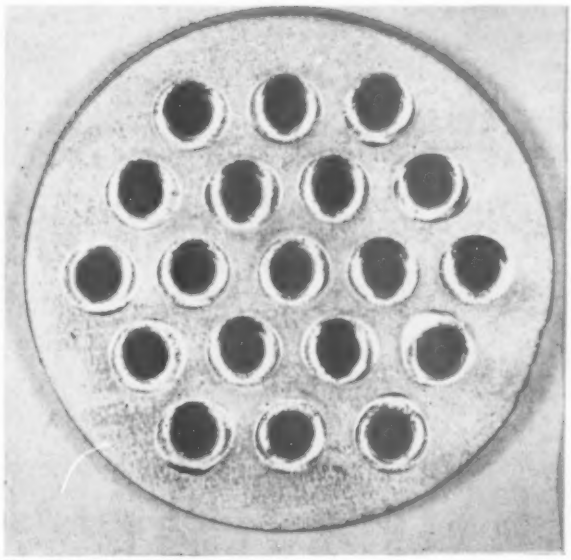

Fig. 11 Typical Cone Arc welded header. Arc distance 0.050 in. Mag. 3.5 ×

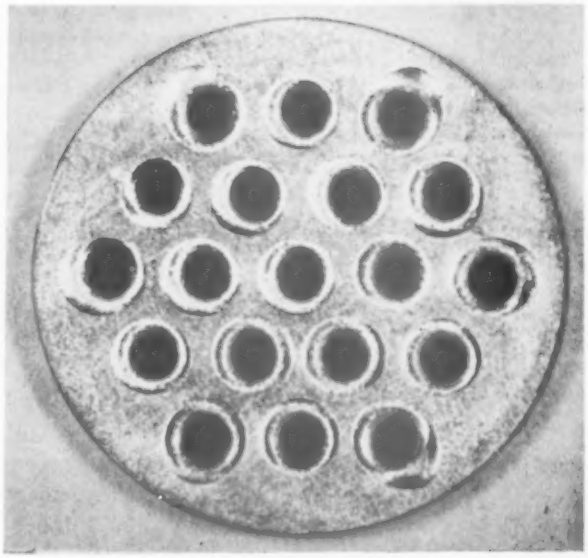

Fig. 12 Typical Cone Arc welded header. Arc distance 0.100 in. Mag. 3.5 ×

These observations also resulted in the choice of the name Cone Arc for the process. To the observer, the arc appeared as a conventional inert-gas-shielded arc in that an intense cathode spot appeared at the tip of the electrode surrounded by a less intense cone-shaped halo, the base of which conformed to the header hole periphery. Experiments using high-speed photography are planned as part of future work to aid in the determination of the exact nature of the Cone Arc.

The predominant effect of increasing arc current over the permissible operating range indicated in Fig. 9 was to increase the value of D_0 with a relatively minor decrease in D_I and a slight increase in P. At the higher current levels, the range referred to as "D_I sensitive and D_0 overlap" appeared, both of these conditions being objectional. In addition to the probability of closing the header hole at higher current levels, D_0 became large enough to overlap the adjacent weld, thereby introducing a possible nonuniform heat sink for the succeeding weld. The introduction of distortion, increasing with increasing current, suggested an optimum current level in the order of 55 to 60 amp at the other conditions described in the graph of Fig. 9. In general, however, it was concluded that the current magnitude was not a critical variable since satisfactory Cone Arc welds were obtained over a relatively wide range of currents.

The effect of arc time on the parameters D_0, D_I and P was determined in a similar manner. The results are presented in the graph of Fig. 10 which reveals behaviors comparable to those exhibited by the curves of Fig. 9. The predominant effect was once again an increase in D_0 with a relatively minor decrease in D_I, and slight increase in P with increased arc time. A minimum time at a given current for a complete weld, a D_0 overlap, and a D_I sensitive range are evident. Since distortion increased with increasing arc time, these curves suggested an optimum current duration of from 1.5 to 2 sec, although a relatively wide range of arc times were permissible for satisfactory results.

Several combinations of Cone Arc welding conditions which were considered as optimum were used in the evaluation of the consistency of results and reliability of the process. A complete 19-hole header was welded for each of these combinations of welding conditions. Figure 11 shows an enlarged view of a typical 19-hole header after welding each of the 19 tubes with the following conditions:

Arc current	55 amp
Arc time	1.8 sec
Electrode	Hi-Thoria tungsten —0.0625 in. diam (pointed 90-deg included angle)
Arc distance	0.050 in.
Argon gas flow	30 cfh
Header thickness	0.125 in.
Header diam	1.10 in.
Header hole-to-hole distance	0.200 in. (center to center)
Tubing (flush with header)	0.100 in. OD, 0.010 in. wall

The effect of arc distance was also investigated. Experiments revealed that longer arc distances required higher currents and longer times in order that consistency might be realized. The header in Fig. 12 was welded using a current of 65 amp, an arc time of 2.0 sec, an arc distance of 0.100 in., and other conditions as described above for weld of Fig. 11. Larger welds, some with nonuniform fusion zones near the header edge, are evident. The increased header distortion resulting from higher currents, longer times and the resulting larger fusion zone indicated that the shorter arc length of 0.050 in. was preferable.

CONCLUSIONS

1. The Cone Arc welding method was found applicable to tube-to-header heat exchanger assemblies involving small diameter thin-walled tubing and headers of the size and material used in this investigation which probably cannot be effectively welded by conventional techniques.

2. Cone Arc welding equipment may be assembled from commercially available and relatively inexpensive components.

3. The major variables, arc current and arc time, were not critical within reasonable limits, indicating that precision control of these variables was not required.

4. A hole-to-hole distance center to center of approximately twice the outside diameter of the tubes was found desirable to avoid overlapping of the fusion zones.

5. By proper selection of welding variables, penetrations of the order of two to three times the thickness of the tube wall could be obtained without objectionable reduction of the inside diameter of the tube. Greater penetration could be obtained only at the expense of a reduction in the inside diameter of the tube by the constriction of the extra volume of fused metal.

ACKNOWLEDGMENTS

The authors wish to acknowledge the services of C. L. Scott, of the Welding Section, in the production of the experimental welds used in this investigation and the members of the Metallographic Section for the photographs and photomacrographs contained herein.

Bibliography

Mann, E. R., "Means for Making Uniform Circular Heliarc Welds by Deflecting the Ion Beam Continuously," Unclassified Document (ANP-63).

Zeno, R. S., and Leslie, H. L. C., "The Inert-Arc Welding of Thin-Walled Tubing," THE WELDING JOURNAL, **30** (11), 986–992 (1951).

Chapin, N. A., Cobine, J. D., and Gallagher, C. J., "Tungsten-Thoria Electrodes for Inert Arc Welding," *Ibid.*, **30** (6), 529–531 (1951).

Jennings, C. H., "Dynamic Characteristics of D-C Welding Machines," *Ibid.*, **30** (2), 117–130 (1951).

Keyte, J. B., "The Effect of Power Supply Characteristics on D-C Welding," *Ibid.*, **30** (12), 1079–1083 (1951).

CURRENT WELDING LITERATURE

Accident Prevention. Make Your Electric Welding Operations Safer, W. Schweisheimer. Iron Age, vol. 171, no. 14 (Apr. 2, 1953), pp. 160–161.

Aircraft Engine Manufacture. Here's How Welding Builds Stainless Steel "Lungs" for B-29's. Industry & Welding, vol. 26, no. 4 (Apr. 1953), pp. 42–43, 45, 73.

Aircraft Manufacture. Set Up, Preparation and Procedure for Welding Navy Flying Boats, L. Barrett, C. Wood. Industry & Welding, vol. 26, no. 4 (Apr. 1953), pp. 64–68, 70–71.

Automobiles, Light Weight. All-Welded Magnesium Body Is Light, Strong and Rigid. Industry & Welding, vol. 26, no. 4 (Apr. 1953), pp. 54–55, 82–83.

Boiler Manufacture. Production-Line Setup Speeds Fabrication of All-Welded Boilers, F. D. Mosher. Industry & Welding, vol. 26, no. 4 (Apr. 1953), pp. 59–60, 62, 92, 94–95.

Brazing Silver Alloy. Rotating Fixtures Speed Manual Silver Brazing. Industry & Welding, vol. 26, no. 4 (Apr. 1953), pp. 47–49, 51.

Electric Cables, Sheathing. Continuous Sheathing of Electric Cables with Aluminium. Sheet Metal Industries, vol. 30, no. 312 (Apr.,1953), pp. 291–295.

Electrodes for Welding 18% Cr–8% Ni Steels, H. F. Tremlett. Welding & Metal Fabrication, vol. 21, no. 4 (Apr. 1953), pp. 136–144.

Heat Exchangers, Manufacture. Dip Brazing Cuts Costs . . . in Making Aluminum Heat Exchangers. Modern Metals, vol. 9, no. 3 (Apr. 1953), pp. 40–41.

Inert Gas. Aluminum Additive Eliminates Porosity in Inert-Gas Arc Welding Operations, M. S. Mirantz. Industry & Welding, vol. 26, no. 4 (Apr. 1953), pp. 75–76, 78–79.

Inert Gas. "Argonarc" Welding Torch. Engineer, vol. 194, no. 5051 (Nov. 14, 1952), p. 666; see also Engineering, vol. 174, no. 4534 (Dec. 19, 1952), p. 807.

Light Metals. Developments in Metal Arc Welding of Aluminium and Its Alloys, W. I. Pumphrey, E. van Someren, M. R. Kilgour. Light Metals, vol. 16, no. 181 (Apr. 1953), pp. 132–135.

Locomotive Manufacture. Production of Modern Locomotives. Welding & Metal Fabrication, vol. 21, no. 4 (Apr. 1953), pp. 124–127.

Machinery Manufacture. Weldments Click in Processing Machines, G. N. Bull. Tooling & Production, vol. 19, no. 1 (Apr. 1953), pp. 47–49, 88–89.

Metals and Alloys. Hardfacing by Welding, M. Riddihough. Junior Instn. Engrs.—J., vol. 63, pt. 7 (Apr. 1953), pp. 213–216.

Metals Cutting. Arc-Cutting Process for Aluminium Alloys. Light Metals, vol. 16, no. 181 (Apr. 1953), pp. 114–115.

Metals Cutting. Electro-Spark Machining, C. R. Alden. Am. Soc. Mech. Engrs.—Paper, no. 53—S-29 (for meeting Apr. 28–30, 1953), 12 pp.

Petroleum Refineries. Modern Pipe Welding Practices, F. C. Fantz. Industry & Welding, vol. 26, no. 4 (Apr. 1953), pp. 37–40, 72–73.

Pipe Welding. How to Weld Pipe. Mill & Factory, vol. 51, no. 6 (Dec. 1952), pp. 128–131.

Radiators, Heating. Sheet Metal Welded Radiators, F. S. Gilbertson. Can. Machy., vol. 64, no. 3 (Mar. 1953), pp. 221–223.

Shipbuilding, Oxygen Cutting. Powder-Cutting Eases Fabrication of Alloy Sheets for Minesweepers, F. M. Burt. Western Metals, vol. 11, no. 2 (Feb. 1953), pp. 69–71.

Soldering. Ultrasonics in Foundry. Electronic Eng., vol. 25, no. 299 (Jan. 1953), p. 21.

Soldering Aluminum. Ultrasonic Soldering in Foundry. Engineering, vol. 174, no. 4529 (Nov. 14, 1952), p. 647.

Stainless Steel. Welding Stainless Steels Has Its Problems, W. G. Blackwell. Steel, vol. 132, no. 14 (Apr. 6, 1953), pp. 138–139.

Submerged Melt. Technology of Automatic Welding in Soviet Union, J. Mannin. Engrs.' Digest, vol. 14, no. 1 (Jan. 1953), pp. 14–17.

Welded Steel Structures. Welded Portal Frame Retort House. Welding & Metal Fabrication, vol. 21, no. 4 (Apr. 1953), pp. 116–123.

Welding Shops. Fabrication in Heavy Engineering. Welding & Metal Fabrication, vol. 21, no. 3 (Mar. 1953), pp. 80–85; no. 4 (Apr.), pp. 131–135.

Welds Testing. Stresses in Circular-Patch Weld-Test Specimens, A. V. Levy, H. E. Kennedy. Engrs.' Digest, vol. 14, no. 1 (Jan. 1953), pp. 7–8.

Resistance Welding Applications in Aircraft Stainless Steels

Specific application of spot and seam welding to assemblies for airframe parts and engines including information on equipment controls and procedures

by D. O. Samuelson

AS A MEANS of introduction to the specific applications of resistance welding of stainless steel, it is desirable that we briefly discuss the types of products and materials handled by the fabricator and their influence on the selection of equipment and processes.

Solar Aircraft Co. is a subcontractor primarily engaged in building hot parts for turbo jet engines. This type manufacture has been a progression and a natural outgrowth of the manufacture of stainless steel exhaust manifolds, which were one of the original products produced some 25 years ago and still a volume product of the company. In dealing with stainless steel and the problems involved in its fabrication, a third line of products—airframe parts—has evolved using the structural stainless steels. One outstanding product in this line is a stainless steel nacelle assembly used on the Lockheed P2V airplane. The resistance welding of these three types of products will be considered in this discussion.

The materials involved in the manufacture of the parts under discussion are listed in Table 1, which illustrates the chemical composition of each type. No attempt will be made to evaluate these materials from a metallurgical standpoint. The austenitic grades, the 300 series, cause us the fewest resistance welding problems and comprise the largest tonnage of steel consumption in our plant. Although this relative ease of operation in the 300 series can be partially attributed to experience in the field, it should be pointed out that this group of steels is not as crack-sensitive as are many of the 400 series and the Inconels.

The resistance-welding process for our applications has brought forth the need for basic welding schedules which are of prime importance in the selection of welding equipment. An abbreviated form of our base schedule is shown in Table 2 for spot welding and Table 3 for seam welding. These tables are by no means a production welding schedule for any given condition, but are used in our shop as target values or starting points in making new setups. The pressure values and the approximate ampere values will indicate the working values and the relative size of welding machine required for our application.

The basic spot-weld machine for the operation in which we are involved requires essentially the following items:

1. An approximate force capacity of 4000 lb is adequate for our top schedules. In addition to the top pressure requirements, this machine must be able to weld light gages down to 0.005 thickness, which necessitates a low inertia system to divorce the head mechanism from the electrode.

2. Current capacities of the standard machine must exceed 18,000 secondary amperes, and we have found that a 100-kva rated machine will adequately provide this capacity at a 36-in. throat depth.

3. The choice between three-phase and single-phase equipment is largely based on economics. We have found that in general the standard single-phase machines are adequate for our use and that three-phase equipment costs must be justified on the basis of advantages in metal combinations or special alloys to be welded.

4. Physical requirements of a standard spot welder include a 36-in. throat depth from the machine body face to the electrodes. We have standardized on two styles of lower horns; one being a swinging or hinged knee type, versatile for offset work, and the other being a long slender stationary arm, which is best suited to our cylindrical work in sizes as small as 6 in. round by 24 to 30 in. long.

5. Control panels for our spot welders are all fully synchronous and are operated from a two-stage, 24-v foot switch.

The roll-welding machine, which is considered standard in our shop, includes the following features.

1. The force capacity of these machines must be 2300 lb, which necessitates a 6-in. cylinder. A low inertia system is essential to our roll welders, which

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Table 1—Types of Material Fabricated

AMS	Nearest AISI	Condensed list of materials									
		C	*MN*	*P*	*S*	*SI*	*NI*	*CR*	*CU*	*MO*	
5517	302	0.15 max.	2.0 max.	0.04 max.	0.03 max.	1.0 max.	7.0 min.	17.0 min.	0.50 max.	0.50 max.	...
5521	310	0.08 max.	2.0 max.	0.04 max.	0.03 max.	0.75 max.	19.0/22.0	24.0/26.0	0.50 max.	0.50 max.	...
5524	316	0.08 max.	2.0 max.	0.04 max.	0.03 max.	1.0 max.	12.0/14.0	17.0/19.0	0.50 max.	2.0/2.5	...
5510	321	0.08 max.	1.0/2.0	0.04 max.	0.03 max.	1.0 max.	8.0/11.0	17.0/19.0	0.50 max.	0.50 max.	...
										Ti	...
										6 × C/0.70	...
5512	347	0.08 max.	2.0 max.	0.04 max.	0.03 max.	0.50/1.0	9.0/12.0	17.0/19.0	0.50 max.	Cb + Ta	...
										10 × C/1.10	...
5504	410	0.15 max.	1.0 max.	0.04 max.	0.03 max.	1.0 max.	0.75 max.	11.5/13.5	0.50 max.	Al	...
	GLS									Sn	...
NAX	AC 9115	0.10/0.17	0.50/0.80	0.04 max.	0.04 max.	0.60/0.90	...	0.50/0.75	...	0.05 max.	0.05 max.
										0.15 max.	...
										Zr	...
5540	Inconel	0.015 max.	1.0 max.	...	...	0.50 max.	72.0 min.	14.0/17.0	0.50 max.	...	...
										0.05/0.15	...
5542	Inconel X	0.08 max.	0.30/1.0	...	0.01 max.	0.50 max.	70.0 min.	14.0/16.0	0.20 max.	Fe	...
										6.0/10.0	...
									Cb + Ta	Al	Ti
	Inconel W	0.08 max.	0.30/1.0	...	0.01 max.	0.50 max.	70.0 min.	14.0/16.0	0.20 max.	Fe	2.25/2.75
									0.70/1.20	5.0/9.0	0.40/1.0
									...	Al	Ti
										Fe	2.25/2.75
5532	N-155	0.08/0.16	1.0/2.0	0.04 max.	0.03 max.	1.0 max.	19.0/21.0	20.0/22.5	Cb + Ta	5.0/9.0	0.40/1.0
									2.5/3.5	Co	W
									0.75/1.25	18.5/21.0	2.0/3.0
5537	L-605	0.05/0.15	1.0/2.0	0.04 max.	0.03 max.	1.0 max.	9.0/11.0	19.0/21.0	Co	Fe	W
									...	Remainder	14.0/16.0
5526	19-9DL	0.28/0.35	0.75/1.50	0.04 max.	0.03 max.	0.30/0.80	8.0/11.0	18.0/21.0	0.50 max.	1.0/1.75	3.0 max.
											W
											Cb + Ta
6350	4130	0.27/0.33	0.40/0.60	0.04 max.	0.04 max.	0.20/0.35	...	0.80/1.10	...	0.15/0.25	1.0/1.75
6355	8630	0.27/0.33	0.70/0.90	0.04 max.	0.04 max.	0.20/0.35	0.40/0.70	0.40/0.60	...	0.15/0.25	...

will allow light pressures of 80 or 90 lb for extremely light work.

2. The current capacity of the standard roll welder must exceed 16,500 amp for our heavy work, and the 150-kva rated machine is adequate for this requirement.

3. As in spot-welding machines, the single-phase machine is standard, although we have on numerous occasions selected three-phase equipment for materials such as Inconel and Type 310 where the production advantages will justify the additional cost.

4. Physically the roll-welding machine must be adaptable for both circumferential and longitudinal work with the change-over being made by shop set-up men without the use of maintenance help. The throat depth of the standard machine is 36 in. with the lower arm slender enough to accommodate a 6-in. diam cylinder. Due to the frequent wheel dressing involved in welding stainless steel alloys, the removal of the electrodes from the machine must be accomplished with ease and, therefore, none of our machines have outboard bearings on the upper wheels.

5. Control panels for the standard seam welders are synchronous single phase and are operated by a two-stage, 24-v foot switch.

Although series welding and indirect welding are specifically prohibited by our specification because of the inconsistencies experienced with this type of welding, we have in our shop some automatic machines employing this type of operation. It should be pointed out, however, that these operations are for tacking only and are not expected to produce certified welds.

Figure 1 shows an automatic machine of this type, which we call the postwelder. The parts to be tacked are shown in the truck at the left of the illustration. On the top tier of the truck are the caps which are assembled to the top of the bodies which are standing on the floor. The skirts shown on the second and third tiers of the truck are assembled to the bottom of the body section.

Fig. 1 Automatic spot tacking machine

Table 2—Basic Spot-Welding Schedules

Stainless steel spot-welding data

Thickness "T" of thinnest outside piece in.	*Net electrode force lb*	*Weld time cycles, 60 per sec*	*Welding current amp*	*Min. lap in.*	*Min. weld spacing in. C to C*	*Diam of fused zone in.*	*Min. shear strength, ult. tensile 70–150,000 psi lb*
0.005	170	2	2,000	3/16	3/16	0.045	55
0.012	260	3	2,100	1/4	1/4	0.076	230
0.020	400	5	4,000	5/16	5/16	0.100	460
0.031	650	7	6,000	3/8	1/2	0.130	850
0.043	975	10	8,700	7/16	11/16	0.180	1365
0.063	1525	14	11,000	5/8	1	0.220	2415
0.078	1900	16	14,000	11/16	1 1/4	0.275	3290
0.094	2375	18	15,700	3/4	1 3/8	0.285	4250
0.125	3300	26	18,000	7/8	2	0.300	5750

Table 3—Basic Seam-Welding Schedules

Stainless steel seam-welding data

Thickness of thinnest outside piece, in.	*Net roll force, lb*	*On time cycles, 60 per sec*	*Max. weld speed, ipm*	*Welds per in., 2T*	*Approx. current, amp*	*Minimum contacting overlap "L," in.*
0.005	300	2	60	20	4,000	1/4
0.012	450	3	50	15	5,600	5/16
0.020	700	4	35	13	7,900	3/8
0.031	1000	6	25	12	10,600	7/16
0.043	1400	6	25	11	13,500	1/2
0.063	1850	8	24	10	15,100	5/8
0.080	2300	8	23	9	16,500	11/16

It will be noted that the center post of this machine contains the RWMA Class II backup or bottom electrodes. These electrodes are brought out inside the part by means of a tapered mandrel, which is hydraulically operated to maintain a consistent pressure. The four top or exterior electrodes shown are hydraulically operated individual cylinders.

Fig. 2 Automatic spot tacking machine with parts assembled for welding

Figure 2 shows this same machine with the parts in position ready for operation. The part location is controlled by locator pins plus the pressure of the internal electrodes. From this point on, the machine is completely automatic. The operator presses the start button, and the external electrodes cycle through the "squeeze," "weld," "hold" and "off" time. During the "off" time, the center post repositions automatically, and the cycle is repeated. This machine makes 16 spot tacks, 4 at one time, using two transformers and one single-phase standard control panel. The

Fig. 3 Forward end of stainless steel nacelle barrel

two seams are subsequently roll welded by two roll welders. The material involved is 0.043 Inconel. This machine was designed and built by Solar in 1947 and has been in continuous service ever since.

Figure 3 shows the forward end of the stainless steel nacelle barrel currently being produced on a production basis. Note the size of the unit, and it is obvious why the major portion of this assembly is welded on portable spot-welding equipment.

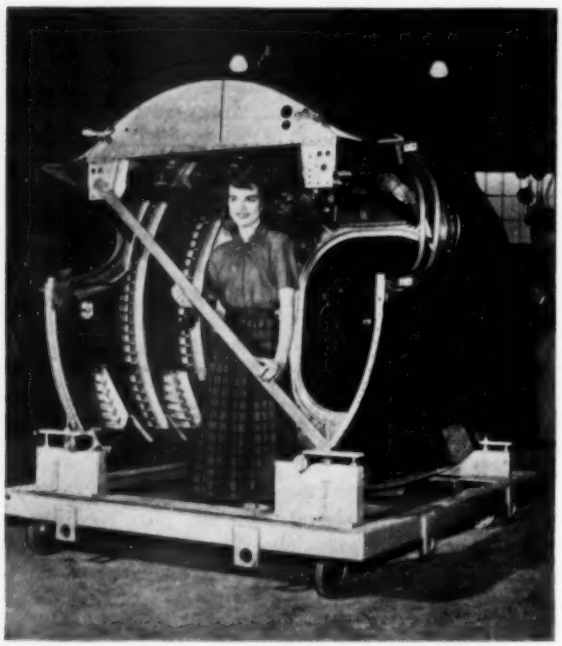


Fig. 4 Aft end of stainless steel nacelle barrel

Figure 4 is taken from the aft end of the same assembly and indicates a portion of the interior structure. Although no physical count has ever been made, it is estimated that there are approximately 35,000 structural spot welds in this assembly, which are made to the MIL-W-6858 (AN-W-32) specification.

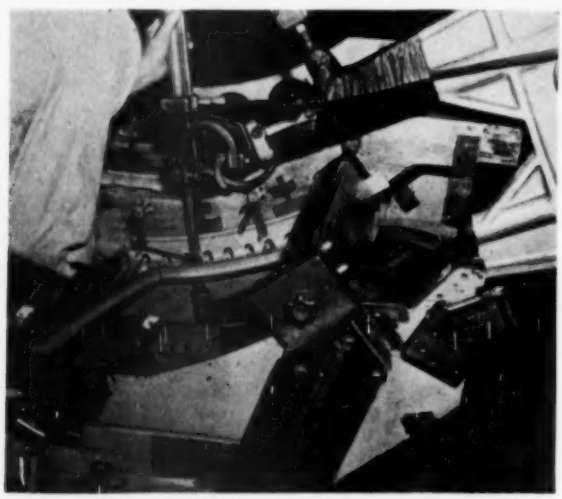


Fig. 5 Subassembly spot-welding gun in operation

Figure 5 demonstrates the use of one of the subassembly spot-welding guns, which was designed and built to be used in the cradle type jig shown. Although the angular head on this gun tends to limit its use, it performs many different operations in the three different jigs which are of the same contour.

Fig. 6 Final assembly portable spot-welding gun

In Fig. 6 the nacelle is standing on aft end, and this gun is welding the forward fire wall to the barrel body. The entire longitudinal seam shown in the figure is welded with this gun. Of particular interest is the offset tip employed in this operation and the hinge in the gun, which allows entrance and removal from the part.

Figure 7 shows the nacelle standing on the forward end and the welding of the aft bulkhead to the nacelle body. Note the extreme offset of the electrodes of this gun. This is a single-purpose gun, which welds four

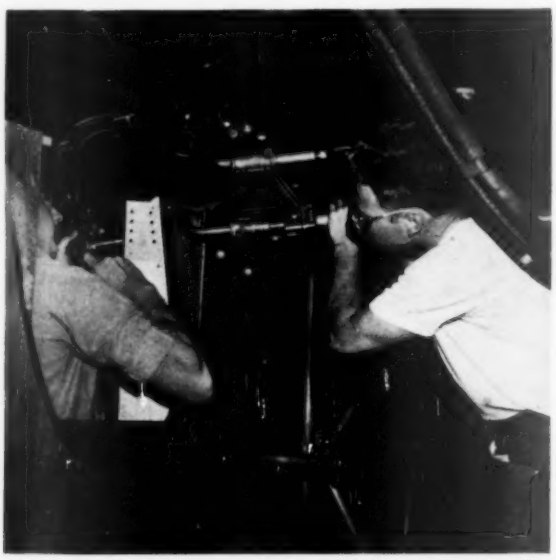


Fig. 7 Single-purpose final assembly spot-weld gun

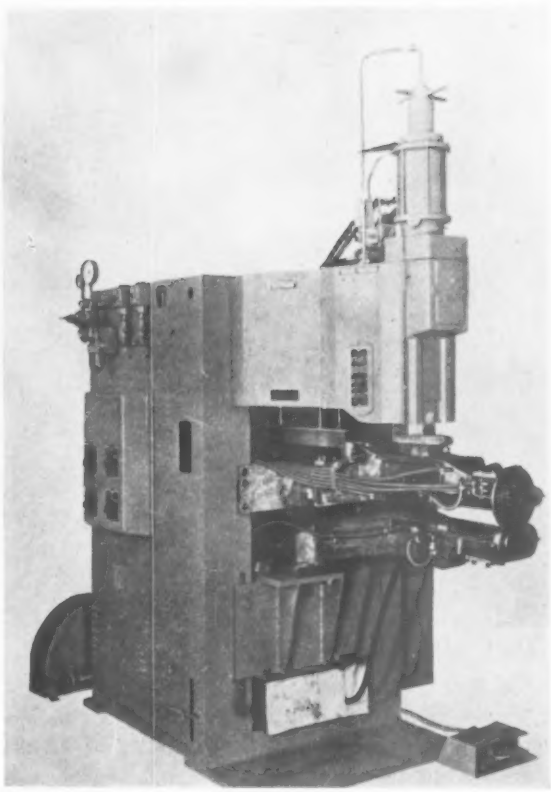


Fig. 8 Special design press type rocker arm roll welder

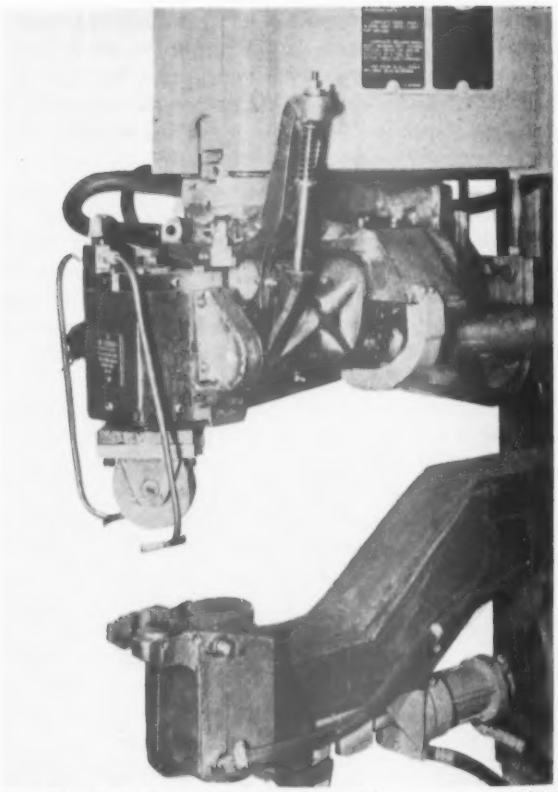


Fig. 10 Special machine for roll welding cone assembly

seams on each barrel, which run from the gun in the pictured position downward toward the inside operator's arm. This picture shows clearly the electric and hydraulic cables, which are 12 ft long, with the transformer and booster mounted overhead.

Fig. 9 Stainless-steel cone assembly to be welded

There are 11 installations of 100-kva transformers with single-phase synchronous controls, which are operating 20 guns on this job. Obviously, this job is not all accomplished on portable equipment, as we recognize the limitations and difficulties of this type operation. We employ portables for certified welding only where it is impractical or impossible to use pedestal-type equipment. Two roll welders and six spot-welders are employed in the subassembly stages of this fabrication. The material involved is primarily $^1/_4$ H, $^1/_2$ H and full H, Type 302 in gages from 0.012 to 0.063.

Of unusual design is the roll welder shown in Fig. 8. This is a combined press type and rocker arm machine and is a three-phase rectifier type. The reason for the unusual design was the necessity of part clearance at the head of the machine, which required the wheels to be 11 in. forward of any machine part. With the material being 0.063 Type 310 to 0.063 Type 347, we were involved in forces of about 1850 lb.

The fulcrum of this upper arm can be seen at the rear of the arm, while the force is applied approximately two-thirds of the way forward. The three-phase design of this machine was selected because of the dissimilar metal combination, the difficulty of maintaining good fit conditions on small $2^3/_8$-in. diam parts, and the lower power demand of this type machine.

This machine is somewhat restricted in versatility; because of its large size it is not well suited for light gages, it can be operated only in the circumferential

position, and the construction of the throat is such that only narrow, flat pieces can be run in the throat area. This machine is currently being run full time on one job, but we have a quantity of this type of welding going through the shop continually for which this machine can be utilized.

Figure 9 illustrates a part which posed some interesting problems for any welding process. The parts to be welded are the 38 approximately $2^1/_2$-in. diam patches which must be resistance-welding gas tight to the cone-shaped body. It will be noted that the interior ring is so restrictive that it is mechanically impossible to spot weld this assembly with one setup or to roll weld this part with any standard setup.

The first pilot models of this part were spot welded using only two offset setups. Analysis of this operation indicated that this was the slowest operation in the line flow type assembly, and the only conceivable single setup which we could devise was a stationary lower electrode with a moving upper electrode. Mechanically this operation could best be adapted to roll welding, and with these basic thoughts, we approached the machine manufacture for engineering aid in the design of such a machine. The results of this design are shown in Fig. 10, which shows the lower electrode in the open position. The action of this jaw is controlled by an air cylinder, which is actuated by a foot switch through an air valve. This lower jaw makes this part self-locating with no chance for operator error. The upper wheel electrode is free running and is propelled by the eccentric drive shaft.

Figure 11 shows a part being welded. This operation, aside from the closing of the lower electrode, is exactly the same as a standard roll-weld operation except that the part does not move or have to be held in position by the operator.

Another feature of this machine is the fact that by removing the drive head assembly and the lower arm, this machine can be set up as a standard longitudinal or circumferential roll welder in a matter of 30 min elapsed set-up time.

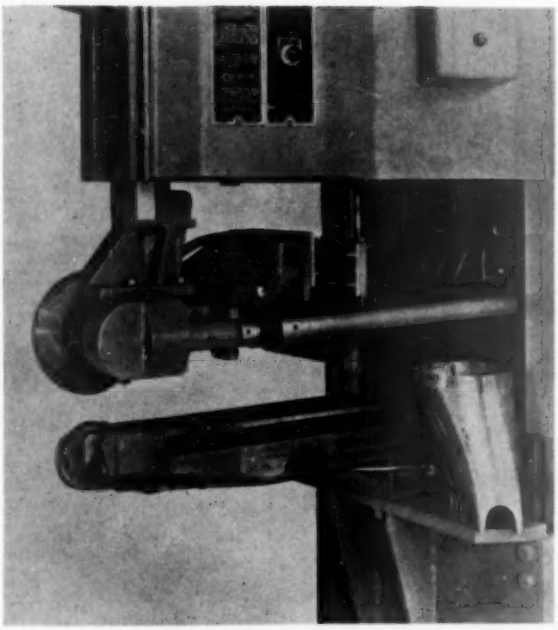


Fig. 12 Transition roll welder with reduced lower arm

Figure 12 illustrates another of our special purpose machines which is of universal design. This machine is a three-phase, 50-kva, 24-in. throat roll welder which is a standard machine except for the lower arm which has been designed especially narrow to accommodate the part shown. The material involved is 0.043 to 0.043 Inconel, and this machine is operated continuously in a production line.

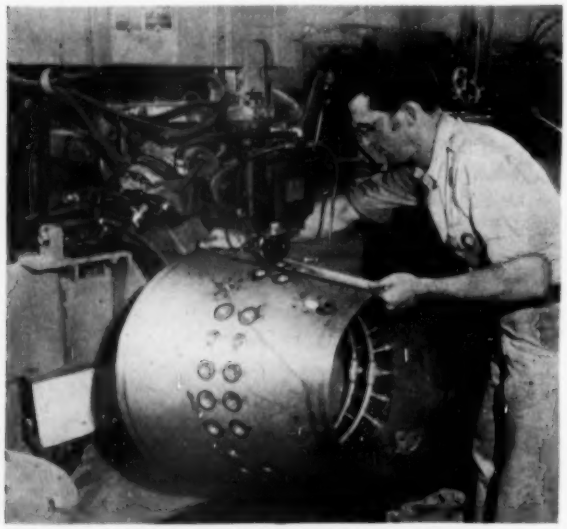


Fig. 11 Cone assembly being welded

Fig. 13 Transition roll welder in operation

It is reasonable to expect considerable lower bearing trouble with this type bottom arm, but we have found that by making the wheel width at the shaft 1 in. wide and allowing the RWMA Class III wheel to run free on the RWMA Class II shaft, the wear is confined to the wheel. This wheel must be replaced periodically because of decreasing over-all diameter due to machine dressing of the welding face, and this periodic replacement assures satisfactory bearing surfaces. Figure 13 shows this machine in operation.

Of particular interest is the tub type drain which we employ on the majority of our single-purpose roll welders which run small parts. This method eliminates the pit type operation, and as is noted in the picture, the operator wears no apron or boots.

Figure 14 is a special purpose machine to weld a circumferential seam on an 8-in. diam part which has longitudinal restrictions. The seam weld involved has a controlled length of plus $^1/_8$ in. minus nothing.

At the inception of this job, the seam was run on a spot welder using repeat operation. This type operation depended entirely on the operator's ability to control the appearance and spacing of the welds. In production line operations, all possible effort is made to mechanize every operation, and the machine in the picture is the result of this aim. The only deviation from a standard machine is the lower arm and a device to de-energize the machine at the end of the weld row. The lower electrode, as is noted, is a segment of a wheel and is adjustable for height by the two Allen screws in the slotted holes. A mechanism was necessary to return the lower electrode to the starting position at the end of the weld row, and this was accomplished by the use of a gear and pinion drive through a shaft, which is actuated by a counterweight attached to the chain drive pulley at the rear of the lower arm. The only other feature necessary to complete this machine was a mechanism to stop the operation, so that the length of the weld row could be controlled, and the upper wheel could not run off the lower electrode. This was originally accomplished by the use of an electronic timer which cut off the operation at a given time after the first spot was made. We encountered difficulty in that the timer was not precise enough to control the operation and because of the difficulty in coordinating this mechanism with the "on" time, "off" time and motor speed functions of the machine. However, this timing problem was eliminated by changing from the electronic timer to a microswitch actuated by an arm attached to the lower electrode shaft. This made the control a function of linear travel rather than time and has proved much more efficient and trouble free. This machine, as well as many of the others, is a result of a coordinated effort of Solar's Welding Engineering Group and the machine manufacturers.

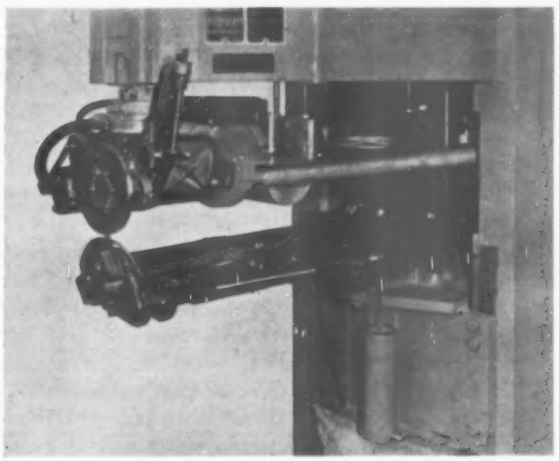


Fig. 14 Segmented wheel roll welder

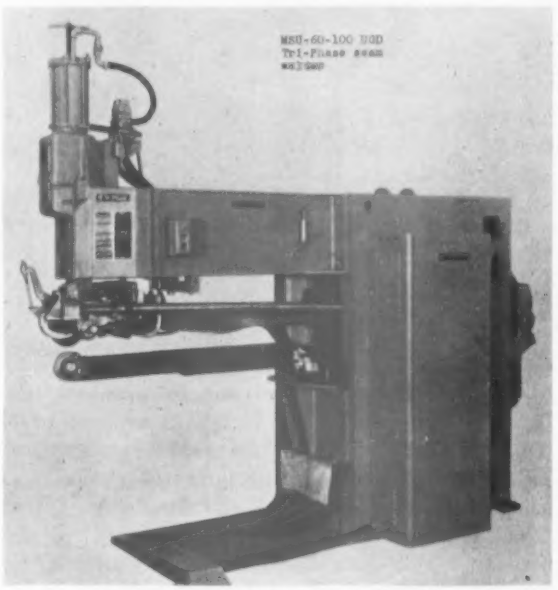


Fig. 15 Sixty-inch throat roll welder

In Fig. 15 can be seen a 60-in. throat machine on which we are currently welding two jobs longitudinally. One of these jobs, 11 in. in diam, has 17 seams, 105 in. long of 0.030–0.025, Type 321 stainless steel. The welding on this unit is overlapping watertight seams and at 24 ipm, approximately $1^1/_4$ hr per unit are required.

Another job which has been continuously run on this type machine is a subassembly tube, which is approximately 10 in. in diam by 44 in. long requiring welding of 0.063 to 0.063 Type 321 stainless steel. There are 16 rows of overlapping spots per assembly, which requires approximately 1 hr of production time per unit. This job, because of the heavy gage, fit conditions and low pressures necessitates operation at about 11 ipm.

One item of interest in this picture is the grease gun shown on the side of this machine. The machine setup man is responsible for the greasing of the machine bearings at given periods throughout the day. This type of machine is operated in a pit which necessitates the operator's wearing boots and rubber aprons. At the present time both of the jobs previously mentioned

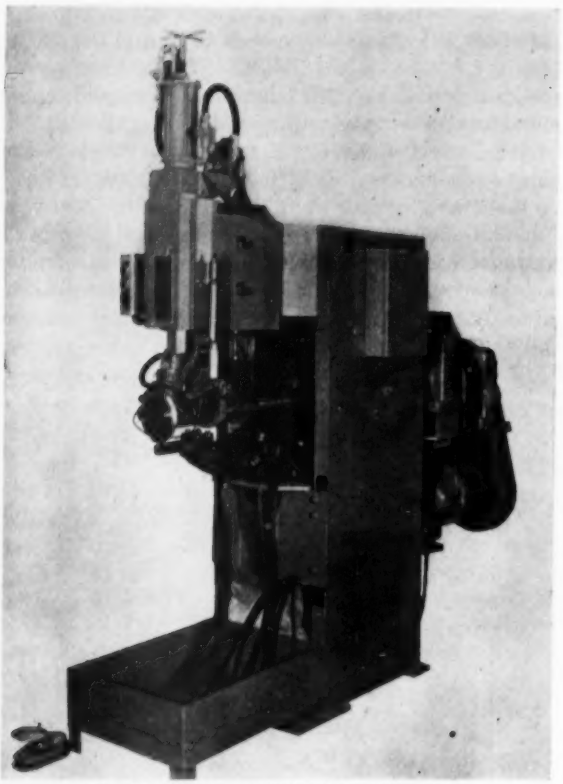


Fig. 16 Universal light duty roll welder

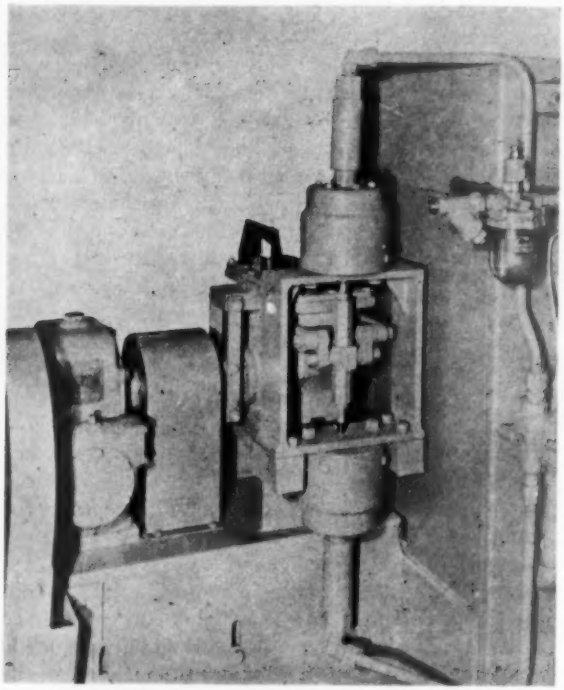


Fig. 17 Intermittent drive mechanism

are being run on these machines by women operators using trucks to support the parts.

The machine shown in Fig. 16 is the result of our need for a light-duty machine especially adapted for welding small parts. The lower arm, which is shown in this machine, contains both the longitudinal and circumferential bars for welding a 1 in. diam by 3 in. long 0.005-in. thick stainless steel tube. The change from the illustrated circumferential position to the longitudinal position is accomplished by rotating the upper head mechanism to the position over the longitudinal lower bar.

At the present time we have two of this type machine in our plant, both of which are operating full time on light gage small parts.

In addition to the adaptability of this machine to extremely light materials, we have the intermittent drive feature added which allows the spot to be made while the wheel is stopped, and the machine automatically indexes to the next spot position. This principal is not uncommon in aircraft, especially among the aluminum fabricators.

Figure 17 shows the opposed piston, air-operated mechanism which drives the roll welder when it operates on intermittent drive. These pistons are air-actuated through electronically controlled valves. The spot spacing is controlled by adjustment of the turn buckle between the pistons, which lengthens or shortens the travel of the overrunning clutch. This mechanism is calibrated by means of a vernier scale which is graduated in degrees of rotation. The conversion from degrees of rotation to spot spacing in inches is plotted on a chart for various wheel diameters. When this machine is set up for operation with the indexing mechanism, the drive shaft is automatically divorced from the motor drive by means of a "free wheeling" clutch, and conversely, when the machine is set up for operation on the motor drive, it automatically is disconnected from the indexing mechanism through the same type of "free wheeling" clutch.

Figure 18 is a photograph of our 6-deg head roll welder on which both the upper and lower electrodes are inclined 6-deg from a vertical position. This type machine is extremely valuable in welding channel-type rings, where it is mechanically impossible to apply the welding electrodes in a vertical position.

Use of this type equipment is somewhat limited in that it cannot be run on heavy material because the bearings will not stand up under high pressure. This inherent mechanical weakness can be tolerated when it is realized that this machine can seam weld parts which would otherwise have to be spot welded at a higher production cost.

As a matter of general interest, our standard electrode material for spot welding tips is RWMA Class II and our standard electrode material for roll-welding wheels is RWMA Class III. Considerable shop experience and experimentation were the determining factors in the selection of these materials as our standards. It should be pointed out, however, that there are a number of jobs running in our shop which use dissimilar electrode materials to obtain proper heat

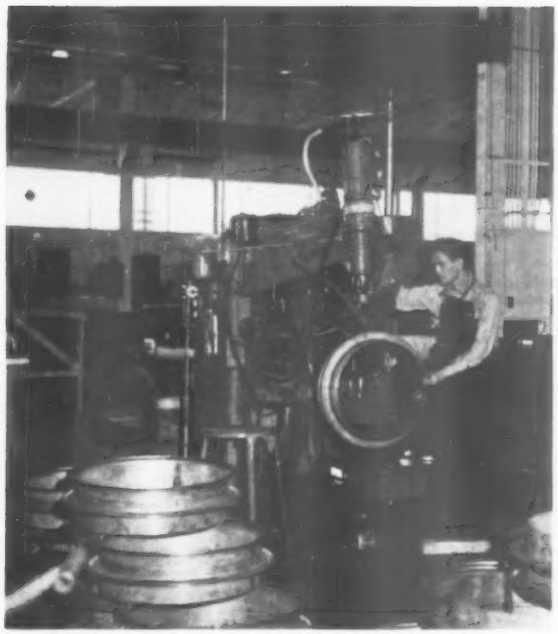


Fig. 18 Six-degree head roll welder in operation

balance. Among these is a roll-weld operation using an elkonite Class 10 tire on a RWMA Class 3 wheel. Other production applications employ the use of elkonite tips on Class H electrodes.

SUMMARY

A summary of the foregoing discussion should point out the following items:

1. As a subcontractor, we do not have design control of many of our products and are faced with the problem of welding the lap, contour, gage and material conditions dictated by the prime contractors.

2. Although we have a number of production line jobs, we are basically a short-run or job-shop fabricator which must make every effort to install universal equipment. We must be able to change machine setups on short notice with a minimum of "down" time. This points up the need for standardization on universal equipment.

3. In the interest of best production methods, every effort is made to adapt standard equipment to specialized high-production machines which will not be obsolete at the end of the production contract.

4. We do not maintain machine design facilities in our plant for resistance-welding equipment. Rather than maintain a staff of highly specialized design personnel, we utilize the facilities and experience offered by the resistance-welding machine manufacturers.

5. The equipment discussed in this paper is the result of the efforts of the welding Engineering Group at Solar Aircraft Co. to meet the demands of the resistance-welding requirements in our type of manufacturing enterprise.

ACKNOWLEDGMENT

The preparation of this paper was accomplished with the generous assistance of F. G. Harkins, Chief Welding Engineering, Solar Aircraft Co., San Diego, and with the aid of the Taylor-Winfield Corp., Warren, Ohio.

Stress Corrosion Cracking of Welds

AS AN index of stress corrosion cracking Rädeker uses the time for fracture of a tensile specimen under constant load in a boiling solution containing 60% $Ca(NO_3)_2 \cdot H_2O$ and 4% NH_4NO_3. In this test aluminum-treated steel (0.19 C, 0.36 Si, 0.94 Mn, 0.053 Al, 0.021 P, 0.024 S) has far better resistance to cracking than similar steels without aluminum. However, the aluminum steel develops high resistance only if it is heated 2 hr at 750° C before use. Heating at 850° C or higher destroys the resistance completely. It is believed that precipitation of aluminum nitride at 750° C and its solution at higher temperatures account for the results.

Welding the aluminum steel presents a twofold problem. First, the heat-affected zone is heated above 750° C during welding, though only for a short time. Second, is the aluminum retained in the weld or slagged with ordinary manual electrodes? Dr. Rädeker mentions these problems without offering a solution. His tests showed, however, that welded joints made with suitable alloy steel electrodes have excellent resistance to stress corrosion cracking after heat treatment at 750° C. Failure occurred outside the weld.

W. Hummitzsch, discussing these results, states that he uses the boiling calcium ammonium nitrate solution and a tensile stress of 36,000 psi to test specimens ($^1/_4 \times {}^1/_8$-in. cross section) of all-weld-metal and welded joints. Cracks occur in either the weld metal or the heat-affected zone $^3/_{32}$ to $^1/_8$ in. away from the weld. Welds high in nitrogen and oxygen are least resistant to stress corrosion cracking. Unalloyed weld metal deposited by a basic coating has higher resistance. Raising the carbon content of the weld from 0.07 to 0.12–0.20% improves the resistance, particularly if 0.30 to 0.60% Mo is added. The weld metal having the highest resistance contained 0.18 C, 0.32 Si, 0.78 Mn, 1.03 Cr, 0.42 Mo, 0.041 N_2, 0.032 O_2. The all-weld metal failed only after $4^1/_2$ days at 33,000 psi. No explanation is offered for the good results with chromium-molybdenum composition, which also had the highest resistance of the wrought steels by Rädeker. A weld containing titanium and manganese had high resistance, too.

Abstract of "Verbesserung der Prüfung von Stahl auf Empfindlichkeit gegen Spannungsrisskorrosion," by W. Rädeker, published in *Stahl u. Eisen*, **73**, 485–492 (Apr. 9, 1953). (Abstracted by Dr. G. E. Claussen.)

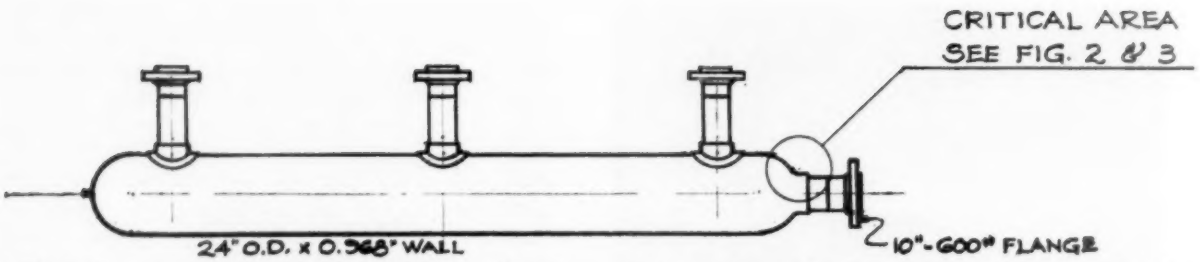


Fig. 1 Compressor bottle with stub connections for a three-cylinder machine. Failure area (encircled) is located at the necked down section where it was welded to the pipe line

Welding Design for High-Pressure Gas Compressor Bottles

by Carl Wurgler

A RAPIDLY expanding market for natural gas, with its attendant need for new transmission lines and increased pressures on existing systems, has necessitated the building of many large compressor stations across the country. With the latter came problems in piping vibration, a condition set up by compressor pulsations which seems to defy solution until the actual installation is in operation. What would normally be considered adequate from the standpoint of welded joints and supports turns out to be a temperamental array of piping that must be delicately balanced and reinforced against the vibration and stresses set up in it.

Carl Wurgler is Chief Piping Design Engineer for the Construction Department of the Dravo Corp.

One such problem, which caused trouble in several compressor stations, was turned over to Dravo Corp. for investigation. It involved piping failures at the compressor bottles (headers connecting multiple cyl-

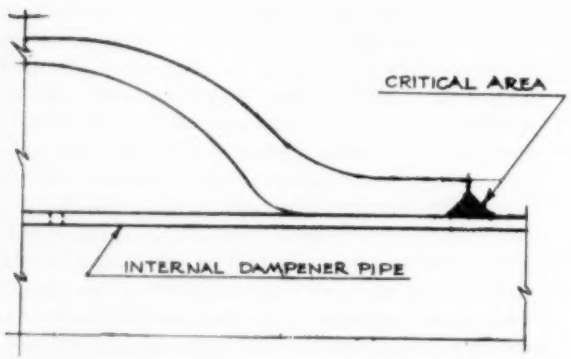


Fig. 2 Enlarged view of one type joint shows how vibration stresses would concentrate at the change-in-direction point of the weld itself. Extra heavy thickness of the bottle, in comparison to the pipe, does not relieve the concentration of stresses in the weld

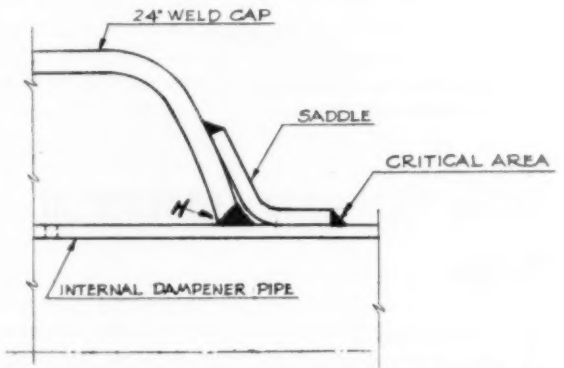


Fig. 3 This type joint also imposes an abrupt change in direction which causes the stresses to concentrate in the welds. Failure of weld in critical area will place all the vibratory stresses in the unreinforced pressure weld H and cause it to fail at this point

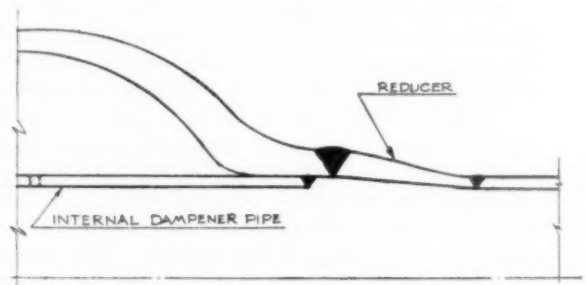


Fig. 4 Solution for the existing installations was to weld the dampener pipe to the internal periphery of the bottle neck, and insert a tapered reducer between bottle and pipe line. These joints have proved entirely satisfactory

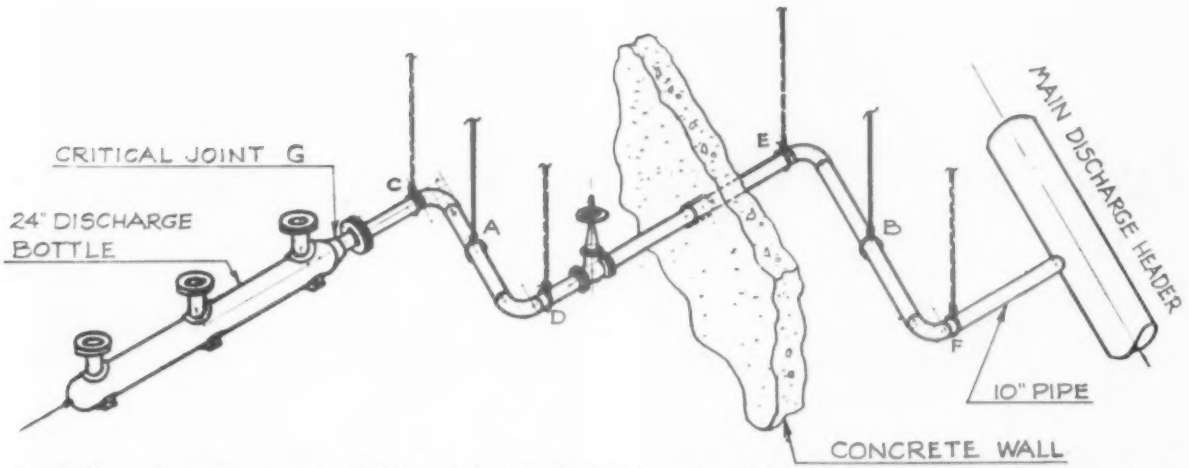


Fig. 5 This schematic arrangement of the existing installation shows the welded joint G that failed. Improperly placed hangers at A and B helped set up vibration. Final location of hangers at C, D, E and F prevented whipping action from pipe overhang

inders of individual compressors) and superficial investigation had placed the blame on defective welding.

Upon inspecting an installation we did find that the welded joint could stand strengthening, but also that pipe hanger relocation would cut down the visible damaging vibration. Pipe overhang and concentrated loads such as heavy flanges and valves, set up a whipping action and cyclic vibration with resulting build up of localized stresses.

The compressor bottles involved, served as both connecting headers between cylinders and as pulsation dampeners. Critical area of failure is shown in Fig. 1, and internal joint construction (two types) in Figs. 2 and 3. As is readily apparent, any stresses transmitted from pipe line to bottle have an abrupt change in direction at the restricted area of the fillet weld, especially at its toe.

Corrective design is shown in Fig. 4, with the pulsation dampener pipe fillet welded to the inside surface of the bottle neck and a special reducer welded in place between bottle and pipe line. The reducer is tapered to match the different thickness of walls of the bottle and line. This streamlined construction permits vibration stresses to pass uniformly into the increased cross section of the bottle with decreased intensity and ultimate dissipation.

Each job was completed by rearranging the pipe hangers as in Fig. 5. Original locations were at *A* and *B* and the two supports were entirely inadequate to restrict pipe whip. These were relocated and two more added so that the arrangement was more balanced, *C*, *D*, *E* and *F*.

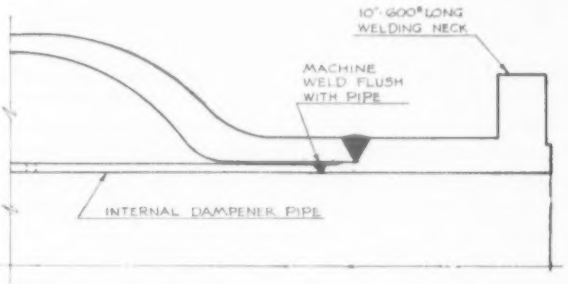


Fig. 6 Suggested connection for new installations incorporates a special pipe fitting machined down on the end to match the dampener pipe, which can be welded before insertion into the bottle. Final weld between bottle neck and fitting makes a substantial joint with no sharp change in direction to concentrate the stresses

Proposed bottle design for new installations will require a change in fabrication as shown in Fig. 6. A long pipe welding neck will be machined at the end to match both the bottle and dampener pipe. Thus, there will be no sharp change in direction and, therefore, no concentration of stresses at the joint.

Inspection Techniques for Quality Welding

Some of the modern nondestructive methods of examining welds are briefly discussed, including visual inspection, radiographic methods, magnaflux, dye-colored penetrant and ultrasonic testing

by Lew Gilbert and Wm. B. Bunn

THE life of a welding inspector is a tough one. Inspectors in other fields have long had as their definite standards of acceptance, micrometers, "go" and "no go" gages, positive physical tests, etc. The welding inspector has many of these also, such as weld size gages, dimensional checks (except that he must too often guess whether the machining stock will be there after machine shop layout men use a different base line from his—which they invariably do) and qualifications tests in confusing numbers with confusing standards.

In addition however, the welding inspector must often read radiographs (X-rays) and must know which type electrode has a pink tip with a blue ribbon, must blow magnetic powder around until he is blue in the face, make all kinds of reports and expedite all matter of materials for the job currently going through the shop. Then the visiting engineering supervisor or customer's inspector (whose reservations, etc., he must also take care of) wonders why the inspector does not keep abreast of the term "Ultrasonic" instead of "Supersonic."

INSPECTIONS IN THE VARIOUS WELDING PROCESSES

Welding processes may be broken down into two major classifications: Pressure and nonpressure. The first classification includes resistance welding which does not, as a rule, lend itself to the usual methods of welding inspection. Here we find quality control of considerable importance, with occasional tests, often to destruction, to check on variables. One notable advance made in this field is the application of statistical control methods to determine tolerance in variables which will assure specific results.

An interesting publication originated at the Westinghouse Research Laboratory in East Pittsburgh not long ago. This demonstrated that uniform high quality spot welds could be obtained by adequate instrumentation in conjunction with established and proof tested schedules covering variables both in welding conditions and material characteristics.

Most of the usual methods of inspection may be equally well applied to all the nonpressure or so-called fusion welding processes. Since, in general, the various weld inspection methods are not competitive, but actually complement each other, very often two or more such methods should be applied to the same joint.

CODES AND SPECIFICATIONS

Governing codes and purchasing specifications ordinarily determine the type and extent of inspection to be applied on the various joints of weldments. Based entirely on the writers' own observations, it appears that present economic conditions in the welding industry have, to a great extent, eliminated use of inspection methods as a means of quality control. This is not a healthy condition since it results in a double standard of quality where there should be but one standard, with the degree of inspection being predicated only on the importance of assuring that the standard is met. Actually there should be little difference in cost between sound, good quality welds and poor, inferior welds since the same motions are necessary to obtain both.

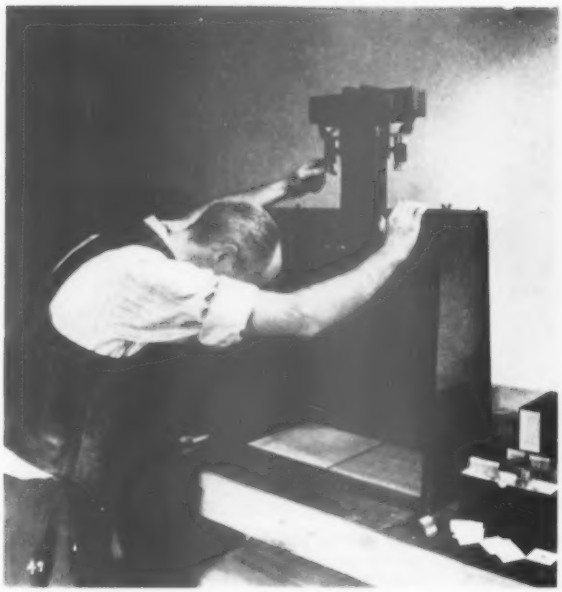
TESTING AND INSPECTION METHODS

There are many tests used in the inspection of weldments; some are seldom applied since they are intended to assure that specific requirements to meet unusual service conditions are met. Among these would be chemical, metallographic, impact and hardness tests. Others more commonly used are various mechanical tests to determine that the operator and welding procedure can make sound welds of satisfactory physical properties; and on pressure vessels, our old friend the hydrostatic test with or without the so-called hammer test. Most of these are made on representative welds rather than on the welding structure and will not be included in this discussion.

Lew Gilbert is Executive Editor of *Industry and Welding*, and **Wm. B. Bunn** is Manufacturing Engineer with the M. W. Kellogg Co.

To be presented at the Thirty-Fourth National Fall Meeting, AWS, week of October 19, 1953, Cleveland, Ohio.

On-the-spot visual inspection of inside welded seam of steel pipe is made by inspector who rides a dolly through the 40½-foot length of pipe



Surface inspection of finished parts. Bench model dual projector permits quick side-by-side comparison of projection replica of standard required surface with one from production line. Projector enlarges image to 30 times on screen in base

Among the most used nondestructive methods of inspection, probably in the order of their frequency of use we have (1) visual inspection, (2) radiographic, (3) magnetic powder, (4) fluorescent or dye-colored penetrating oil and (5) the baby of the group—ultrasonic testing.

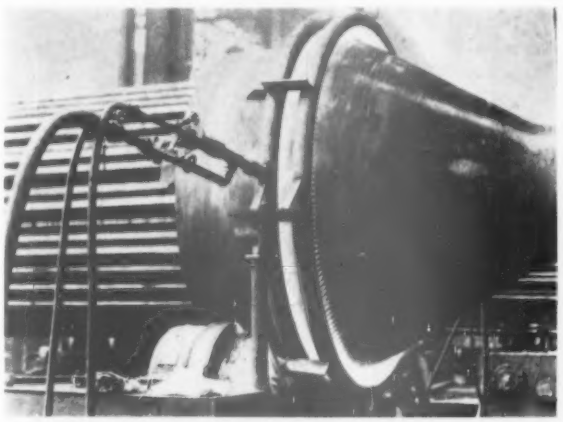
Visual Inspection

Visual inspection is not too interesting a subject, yet it is important since it is the only inspection given to a great many weldments, and it does or should supplement other inspection methods where they are specified. Visual inspection should begin on the components of the welded assembly, and should be performed at definite stages during fabrication. It is especially important: (1) at the time of fit-up prior to welding, (2) after root chipping or gouging and (3) upon completion of welding but prior to postheat treatment, if required.

There is usually little question about type of defect, or dimensions of either welds or assembly during visual inspection. The major problem generally ensues from the fact that time in the production schedule is seldom allotted to inspection except in the final stages. Therefore, minor repairs often assume major proportions due to lack of time prior to shipping or to the fact that stress-relieving or testing operations will have to be repeated. A strong shop inspection force or quality-minded shop supervisors are of great assistance to outside inspectors in covering visual inspection prior to the final inspection. One other method of inspection that deserves comment is that of removing weld probes by trepanning. It is a sampling method which may or may not find defects in a defective joint since it examines only at one location. Where other means of inspection are not available it does serve the definite advantage of keeping the operators on their good behavior.

Radiographic Inspection

This has proved a most effective means of checking weld joints. We find various ways of producing radiation for radiographic purposes, each method having certain limitations which prevent it from monopolizing the field. This results in inspection tools that are again complementary, rather than competitive. X-rays and gamma rays are electromagnetic waves of short wave length capable of penetrating materials opaque to longer light waves. Although these waves penetrate



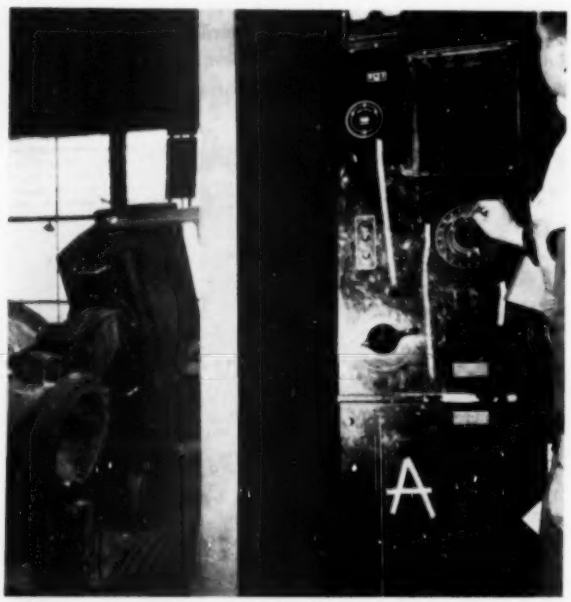
Careful control of preheating and postheating can do much to eliminate weld defects. Recycle catalyst cooler here is slowly rotated to maintain even heating. Thermocouples on inside record temperatures

Preliminary inspection of pipe qualification tests. Welding supervisor gives operator "on-the-spot" instructions on use of new type electrode before test is completed

X-ray technician points out weld defects to welding operator

opaque materials, some of the radiation is absorbed, the amount depending on wave length, density of the material and thickness. Therefore, if a void exists in material of uniform thickness, the effective thickness through the section with the void is less than where the material is solid, resulting in more radiation passing through the area. Since radiation affects photographic film emulsion in proportion to its intensity as well as time, the area of film under a void will receive more radiation than adjacent areas and will therefore appear darker, in effect a shadow image of the defect or void.

Development of X-ray. Rontgen discovered X-rays in 1895. Other investigators in Europe soon began work on radioactive materials. A Frenchman, Bequerel, probably made the first radiograph of metal using gamma rays from an uranium compound. Little was done in this field, on either side of the Atlantic, until 1928, when the Naval Research Laboratory in Anacostia, Washington, D. C., undertook studies in the application of gamma rays to inspection of naval components. Mehl began this work, but was soon joined by Barrett, then Doan, and still later Briggs and Gezelius. This work has continued to the present, and publications from this group are today considered the most inclusive and important published on the subject.



X-ray is used to examine flange weld on large nozzle. Unit is 250-kva portable machine

All radioactive substances disintegrate with time. The rate is measured by the time to reach a strength of half its present strength. Uranium is supposed to have a half-life of about 5 billion years. Radium has a half-life of 1580 years and costs about $30,000 a gram. Radium breaks down into a gas called Radon, which has a half-life of a little less than 4 days. This is often used in medical treatments, but not often for industrial work. The usual form of radium is the salt radium sulfate. When this is sealed it reaches equilibrium with the Radon in about 30 days, and thereafter emits rays of constant intensity for all practical purposes. Two of the advantages in the use of radium are its portability and its penetrating power. Its chief disadvantages are the high exposure times required due to its low intensity as a source of radiation, and, secondly, the lack of contrast in gamma graphs, making flaw detection difficult, especially in thinner sections. Very fine-grained films and the use of double films overcome this deficiency to some extent.

X-ray Inspection. Pioneering work in the industrial application of X-rays probably began at Watertown Arsenal in 1922, when a 200,000-v installation was au-

thorized by the War Department. Dr. H. H. Lester, who is still active in radiographic work was the civilian responsible for the early work which was principally concerned with the improvement of foundry practice.

During the 1930–32 period when the ASME Boiler Code Committee approved the use of welded pressure vessels for boilers and certain unfired uses if the main joints were radiographed, several pressure vessel shops installed X-ray machines of approximately 200,000 v. Since the penetrating power of X-rays is proportional to tube voltage, maximum thickness of material that could be successfully X-rayed was in the 2- to 3-in. range. We say "successfully," because scatter of rays or secondary radiation due to the primary rays striking particles in the material being X-rayed causes excessive fogging which reduces contrast. By the middle thirties, 300,000- then 400,000-v units had been produced, which made possible X-rays of material in up to 5 in. or more in thickness. Developments in X-ray film also served to improve the contrast or definition obtainable.

In the early forties, industrial X-ray tubes of 1,000,000 then 2,000,000 v were produced, providing X-rays in the gamma-ray range of the spectrum, but with sufficient intensity to reduce greatly the exposure time required to inspect steel up to 12 in. in thickness.

It has been said that the 1,000,000-v tube emits radiation equal to $8^1/_2$ lb of radium. It will reduce exposure time from 4 hr where radium is used to 2 min. Yet the 2,000,000-v tube will be about 78 times as fast as its little sister on 8 in. of steel, reducing exposure time from $4^1/_2$ hr to less than 4 min. With these machines it is possible to simultaneously expose an entire circumferential seam, or several objects in a circle around the tube end.

Radio active material (Cobalt 60) is used for weld inspection. Remote control device allows operator to handle material from a safe distance

Major difficulty in the use of X-ray inspection has been its lack of portability. This problem increases to impossible proportions as voltage requirements of the job increase, since the 250,000-v unit is, to our knowledge, the largest that can be considered portable. With all of the rigging necessary to move this equipment it is usually justified in time saving on field pressure vessel work, due to the shorter exposure time compared with use of radium. The use of equipment with the transformer separate from the tube case, connected to it by high-voltage cables, increases portability of X-fay equipment, but in normal field work difficulty is often encountered with breakdowns in these cables. Newer really portable equipment, now available, may ease this problem.

Betatron. A more recent development in the radiographic field is the "electron accelerators"—the betatron and synchrotron which produce radiation of 7,000,000 to 100,000,000 v, and with possibilities of a billion volts with the latter. Sensitivities as great as $^1/_2\%$ have been obtained through 10 in. of steel with a 10,000,000-v generator at the Naval Ordinance Laboratory. The economic use of these high-voltage units is a question for the future to settle. One advantage now being explored is their use in stroboscopic studies of internal moving part.

Cobalt 60. Another recent entry into the radiographic field is the use of the radioactive isotope called Cobalt 60. It has a much higher intensity than the equivalent weight of radium, and may find use in the inspection of heavy sections of castings.

Magnetic Powder Inspection

This method was used on weldments prior to the war but really came into its own during the war. It is a most convenient method, and is surpassed by none for surface inspection of ferromagnetic welds. We do not intend to imply that subsurface defects will not be disclosed, but they may be missed if the contour of the piece or of the defect or other conditions are not just right, whereas a surface defect can be detected almost regardless of technique if one is looking in the general direction of the flaw.

Some readers will remember about fifteen years ago, when shop chippers would throw a handful of dust from the shop floor into the root chipped groove, blow it out with the exhaust from their hammer, then look for areas where it stuck in the groove. They were actually using the magnetic iron oxide of the dust, and the residual magnetism from welding to inspect for defects. Still later, after reading about magnetic flux and obtaining powder from a commercial supplier, cables were wrapped around shells and nozzles and through nozzles; and we broke our backs carrying home-made coils around trying to induce a little magnetism into the right place, so that the powder would find something we could not see better without it. Then the term "Circular Magnetization" (magnetization produced in the work by passing an electric current directly through

Magnetic particle inspection can be used for surface and sub-surface flaws in ferro-magnetic welds. Iron powder outlines weld defects

it) changed the entire aspect of magnetic powder inspection. "Bipolar Magnetization" (passing a current through another conductor to induce magnetization in the work) still has some functions when properly applied.

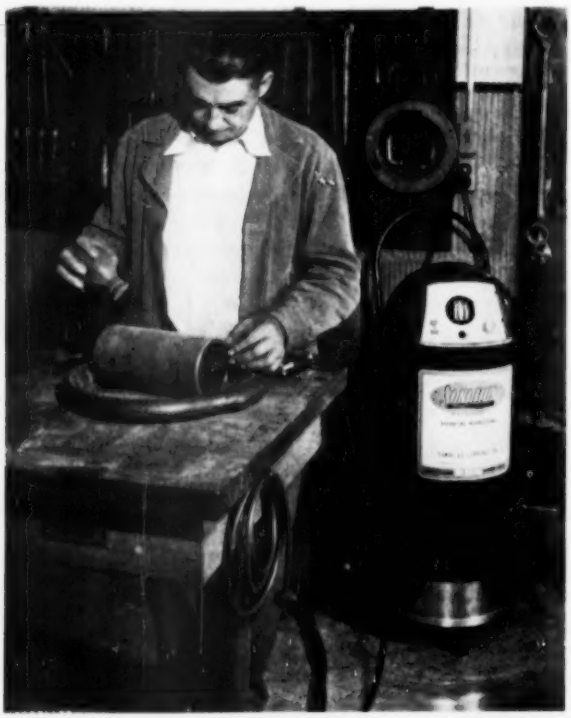
We will not discuss the wet method since it has little application to weldments outside of the aircraft field; nor the "residual method," since few weldments will retain sufficient magnetization to make this satisfactory. In the dry continuous method using circular magnetization, contact prods are placed on or across the weld, and a current is made to flow between the prods. While the current is flowing a magnetic powder is dusted between the prods and is made to move, generally by a gentle air blast. Flux leakage caused by a surface or a subsurface discontinuity will hold the powder, thus outlining the defect.

Weld surface is always a factor in this method of inspection since undercuts, valleys between beads and other surface discontinuities will give false indications or may mask true indications.

Fluorescent or Dye-Colored Oil Penetrant Testing

This is a recent modification of that old machine shop method of detecting surface cracks in piston rods and similar machined surfaces. By the old and effective method, a light oil such as kerosene was applied to the surface, then the surface was wiped clean and a whiting wash was applied and allowed to dry. The oil would seep out of any cracks it had entered and wet the whiting, thereby revealing itself.

Present methods are more effective, since the penetrant contains wetting agents which will help it to enter even microscopic cracks. The oil also has emulsifying agents to aid in its removal by water washing. The talclike powder will absorb with great affinity, and the fluorescent material contained in the oil, for



Magnetic coil and metallic particles are used to check tubing for cracks and fractures. Welded joints can be tested for surface flaws with this new type vibro-magnetic-inspection method. 110 volt a-c and d-c models are available

Dye penetrant method is used to inspect welds in special stainless steel pressure vessel at early stage of fabrication

that method, will show up like a sore thumb under the "Dark Light" or near an ultraviolet inspection lamp. The dye-colored oil is not quite so apparent, but seems to be effective if inspection is close.

Again, surface conditions are important since crevices or corners will hold the oil and give false indications.

A modification of this means of inspection has been used as a substitute for a gravity water test for tightness in thin-walled stainless tanks that could not conveniently be closed for a pressure test. The oil is applied liberally to one side of the joint and left overnight. The next morning the other side of the joint is examined for seep-throughs. The results are better than a gravity test, and may equal pressure testing for small pinholes which are difficult to see with a conventional hydrotest.

Ultrasonic Inspection

This method is in its infancy. It came into the inspection field about eight years ago, and has done a noble job in shafting, heavy forgings and similar places. It is applicable as a routine means of inspection on some classes of forgings, where over 20 man-hours machinery time is required. It may also be used for inspection of some classes of pipe going into high-temperature service. Some of its disclosures in this pipe would curl your hair if you had to operate high-temperature equipment knowing the defects were present.

A few years ago we were unsuccessful in applying ultrasonic testing to turbine forgings and to other work, although it did give promise in detecting poor bond in alloy-clad plate. With the later Sperry equipment using angle searching units we have much more confidence, but as yet we have not applied it to weld inspection to a great extent. The degree of weld finish on both sides of the joint is an important factor that increases the cost for this inspection, and makes it unsuitable for some joints. The evaluation of indications will require extensive work.

Some more or less successful work was performed by several pressure vessel fabricators two or three years ago to determine if ultrasonic testing could be used to determine the quality of heavy plate, and to attempt correlation of indications with weld defects from high-current submerged arc welding. Although these attempts were not very successful, it is believed that greater success would be had with present-day equipment.

Portable ultrasonic instrument is handy for weld testing. Echoes produced by machine reveal internal flaws two to 20-inches in depth

SUMMARY

Some folks say that welds never fail, therefore, why waste energy with inspection. Considering the short time that welding has been used as a major means of fabrication, and the complete on-the-job education that has been required of engineering and fabricating personnel, the record of failures is remarkably low. But welds do fail—ask any refinery man. Even most shop welding men have seen failures in weld joints due to their own shrinkage stresses. From time to time in weld joints that have not failed in service, defects are accidently found that make the finder say a little prayer of thanks for that built-in "factor of safety."

Suppose we go back to 1930, when modern welding was relatively young, and apply welding with the same degree of inspection given riveted joints—a tap and a pressure test. You would today probably be paying more for your gasoline, your electric power and other products. Inspection has forced controls on quality, and forced improvements through research into ways of making joints better as well as cheaper. These controls and improvement in quality and dependability made necessary by rigid inspection have sold welding to many of the industries now making use of it. Without the advances in the art as well as the assurance derived from inspection records, we doubt that electrical generators operating at pressures above 1500 lb and at temperatures of 1050° F would be making a kilowatt hour of electricity with less than a pound of coal—as they are today—compared with 3 lb to do the same job earlier in this century.

Inspection has done a lot to make welding successful in the applications where welding has been most successful. Also, we feel that some of the pressure-welding processes suffer due to the difficulty of applying normal inspection methods to joints made by them.

CONCLUSION

Of all the parting words of advice that might be offered to welding inspectors—or to shop personnel responsible for quality control—perhaps the simplest and best is "Get a copy of the *Inspection Handbook*, published by the American Welding Society." With this little book, some commonsense thinking and a lot of diplomacy, successful inspection is practically assured. And success should be measured by satisfactory weldments produced, not by weldments held up by inspectors for repairs. A good inspector, with the full cooperation of those responsible for production, should have full and complete answers to the question: "How good is good enough?"

PRACTICAL WELDER AND DESIGNER

Provide for Expansion and Contraction

by J. A. Fluharty

IN PREVIOUS issues of the Journal were explanations of how metal expands and contracts and how distortion in welded parts can be prevented. In this article you will see how expansion and contraction works on restricted parts and determines what jigs, work-holding devides or other mechanical devices you will need for your welding jobs.

Many jobs require welding on parts which are re-

J. A. Fluharty, Linde Air Products Co., San Francisco, Calif.

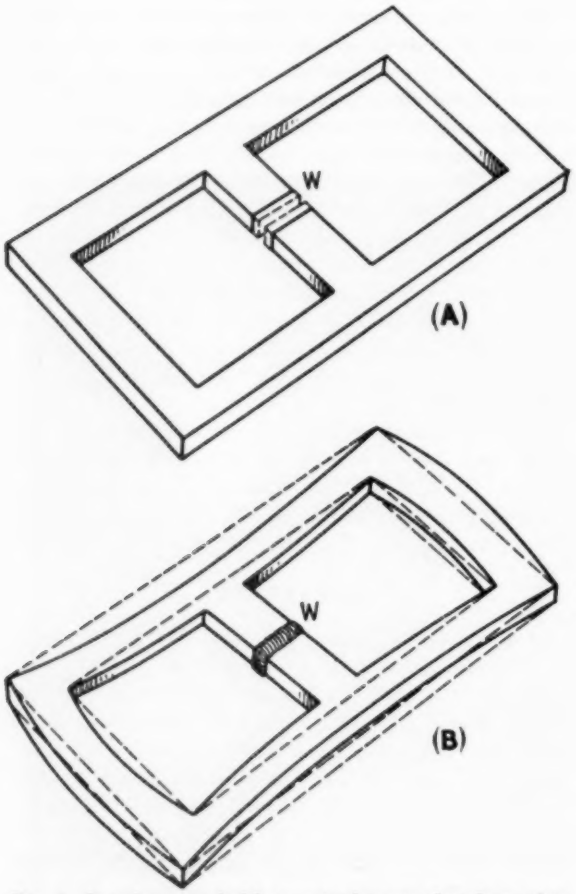


Fig. 1 You have probably repaired parts that have this basic form. In welding a break at W in this type of restrained part, molten metal is added to the center span. When the weld cools, contraction forces tend to pull the part into the shape shown in B

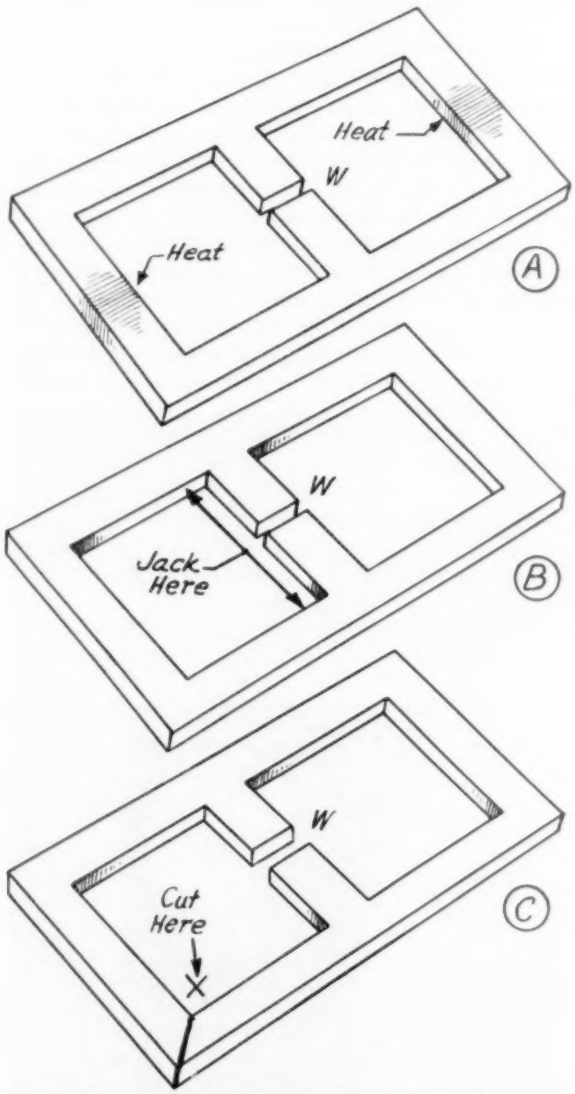


Fig. 2 There are three methods that can be used to make this weld and avoid breaking or warping. These are shown here. Preheating the entire part will also prevent it from warping. However, only small parts should be completely preheated

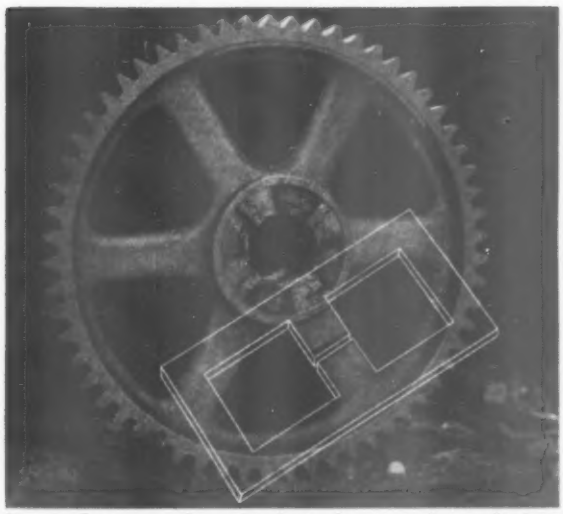


Fig. 3 Let us see how this basic form can be applied to similar parts. Here is a gear with a cracked spoke. The basic form is drawn in white over the gear. Although any of the methods shown in Fig. 2 can be used to make this repair, method A would probably be the easiest one to follow

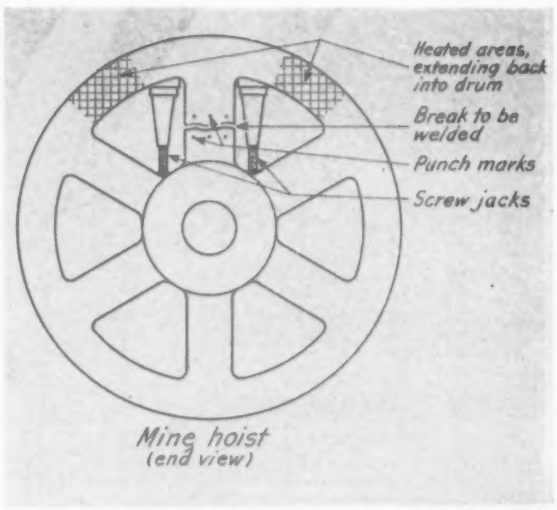


Fig. 4 This large hoist drum was repaired using two of the methods shown in Fig. 2. Punch marks were used to measure the expansion before welding. Jacks and local preheating stretched the broken ends apart before welding. When the weld cooled, the spoke contracted to its original length

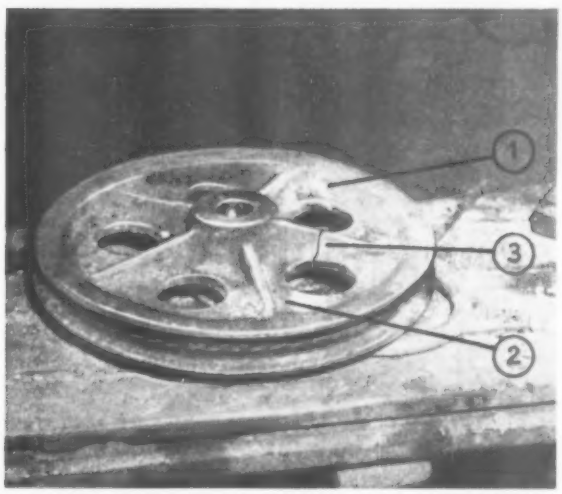


Fig. 5 Here is another example of repairing a "restricted" part. Three spokes were broken in a cast-iron sheave. The spokes were adjoining and only one—the middle spoke of the three—was completely cracked. By welding the spokes in the order shown, distortion was completely eliminated

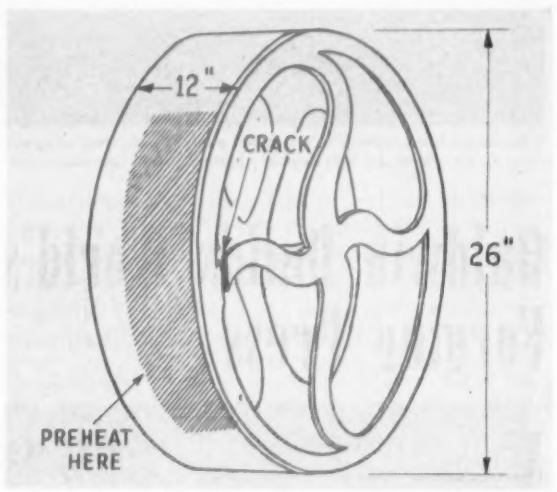


Fig. 6 This cracked roller casting was repaired by proper use of preheat. Local preheating with the blowpipe was confined to the rim near the broken spoke. A black heat relieved stresses and spaced the crack for welding

strained so there is little or no room for expansion and contraction. Your success in welding in these parts will depend on your judgment and experience. Here are several examples to help you understand what happens during welding of restrained parts.

The welding operator should remember that the forces of expansion and contraction are so great that he cannot prevent them, but he can control them. In fact, they must be controlled and understood before a good, sound welding job can be done.

The two side platens assembled with horizontal columns for checking and tests. Forged steel cylinder for horizontal ram is in place in left-hand platen. Also in place on the left-hand platen are the pullback crosshead and cylinders

Baldwin Builds World's Largest Split Die Forging Press

NEARING completion in the Southwark shops of Baldwin-Lima-Hamilton Corp. is the largest split die forging press in the world. Upon erection in the plant of Cameron Iron Works, Inc., Houston, Tex., the press will stand as high as a 6-story building and the supporting foundation will contain a pit 40 ft deep.

The new pull-down type press, with a capacity of 11,000 tons, will be equipped with a piercing ram at the top and knock-out ram at the bottom, and two horizontal side rams for clamping vertically split dies, or for piercing when using horizontally split dies. Main pull-down capacity of the press will be supplied by two 51-in. diam. 60-in. stroke, single-acting cylinders of 5500 tons each. Two $18^1/_2$-in. cylinders, with a net stripping capacity of 300 tons, will be used as pullbacks. With a bolster area of 10 x 10 ft. the press will have a maximum vertical opening of 12 ft and maximum horizontal clearance between side-ram faces of $15^1/_2$ ft.

The two horizontal side-ram cylinders, each made from a single steel forging, have a capacity of 6000 tons

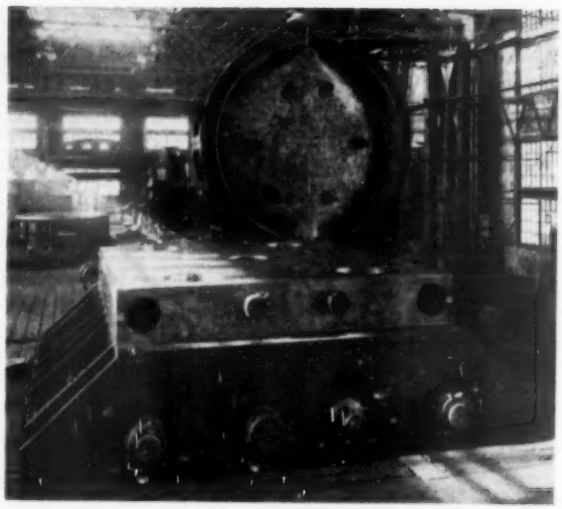


Fig. 1 Center section of the press bed fabricated from steel plate and weighing 260,000 lb. The large tie bolts at the bottom are used to connect a cheek section (containing the downstops) on each side

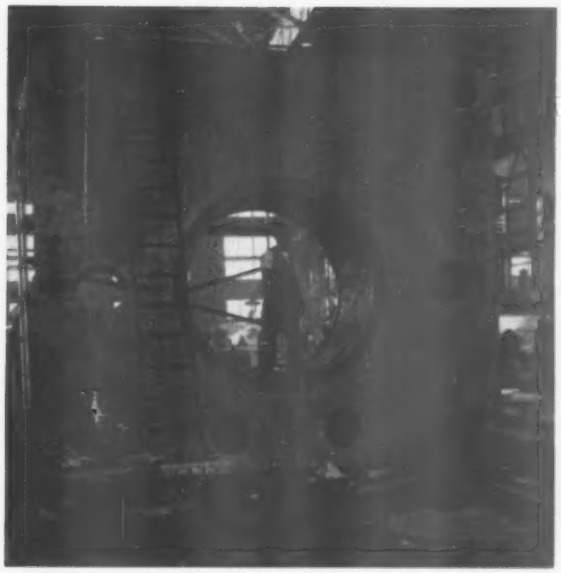


Fig. 2 One of the side platens set up in the erection bay of the Southwark shops. Two such platens, each weighing 200,000 lb, are furnished with the press. Center opening will hold one of the horizontal ram cylinders. Entire piece is of welded plate construction with cast-steel column husk inserts

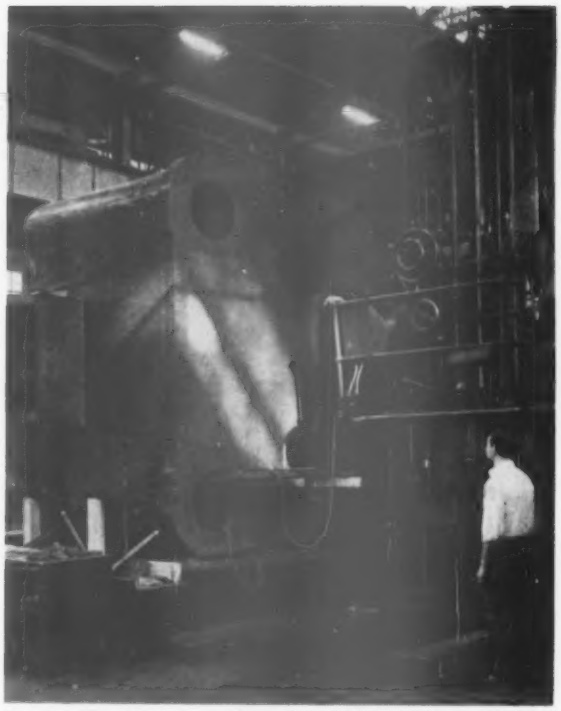


Fig. 3 Massive top moving-down platen being machined on the horizontal boring mill. Weighing about 297,000 lb, it is fabricated from steel plate with cast-steel column husks welded integrally into the platen. Extension on the end is for connection to pullback cylinders. Opening for top piercing ram is behind boring mill

at 8000 psi. Each ram is 48 in. in diameter with a 24-in. stroke, and two pullback cylinders on each side have a total capacity of 500 tons.

Top piercing capacity of 3000 tons is furnished by a single 38-in. diam, 24-in. stroke cylinder. Two pullback cylinders will supply 300 tons net stripping capacity. The piercing ram extension contains a motor-driven spindle threaded on its lower end to engage the piercing tool. A double-acting bottom-piercing cylinder will have 750-ton piercing and 280-ton pullback capacity.

All of the platens, base, etc., for this mammoth machine were fabricated from steel plate, some of which is $6^1/_2$ in. thick. Before welding, it was necessary to preheat the plates with gas torches. After each part was fabricated complete with bracing plates, column husks, etc., it was placed in Baldwin's heat-treating furnace for stress relieving. Some idea of the amount of electric arc welding and time involved to fabricate plates of such thickness can be visualized by the fact that 64 miles of welding wire went into the job.

Each side platen weighs 200,000 lb and the base, complete with check sections containing the downstops, weighs 660,000 lb. Construction of the base in three sections was necessary to keep within permissible shipping dimensions because only three railroad cars capable of carrying such loads are in existence.

The hydraulic actuating system will include three low-pressure (125 to 150 psi) vessels with a useful capacity of 1500 gal; three high-pressure bottles (4950 to 5500 psi); three 5500-psi, 250-hp triplex pumps, the necessary air compressors, and pressure intensifiers to build hydraulic pressure up to 8000 psi.

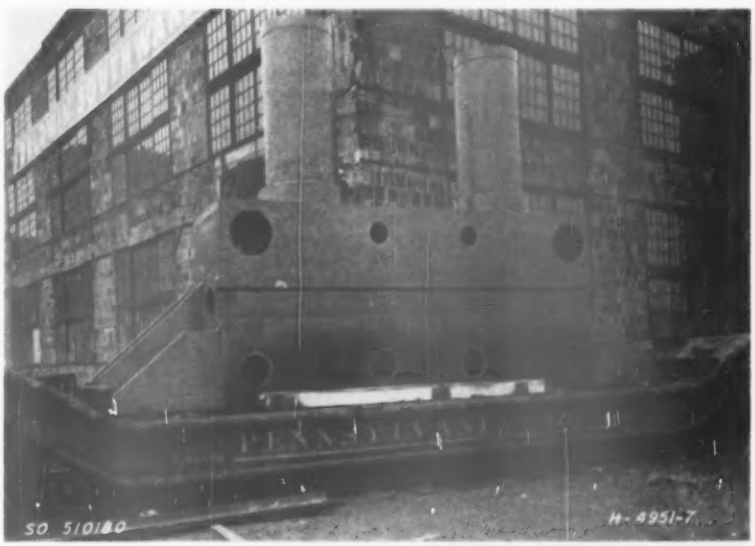


Fig. 4 One of the two check sections containing the downstops, which bolts on each side of the base shown in Fig. 1. It is fabricated from steel plates and contains cast-steel column husk inserts. The downstops are also steel castings. Total weight including downstops is about 200,000 lb

The pump house control panel will be provided with a graphic panel board on which will be a flow-diagram likeness of all pumps, bottles, rams, etc. A glance at the board will tell the engineer how each unit is functioning during press operation.

When the new press goes into production to increase the facilities for split die forging work at Cameron Iron Works, it will be another step in this process which the company pioneered many years ago by installing the first press for such a method. It was the first approach to the broad field of intricate shapes and forms that, heretofore, had been limited to steel castings. Forgings produced in closed, split dies need practically no draft and there is little or no flashing to be removed from the rough part.

Welding Time on Minesweeper Stacks Cut in Half

THE Harbor Boat Building Co., of Terminal Island, Calif., recently cut by 50% the total welding time needed to build aluminum stacks for minesweepers. This was accomplished by changing to sigma welding. The stacks are made from 61S-T6 aluminum sheet, which is welded onto a framework of aluminum angles. They are elliptical in shape: 9 ft long, 5 ft 6 in. wide, and ranging in height from 11 ft, 4 in. to 14 ft, 2 in. When completed the stacks are used to house the five exhaust mufflers from the Diesel engines of Class AMS-60 Minesweepers.

The metal is prepared for welding by power brushing with a stainless steel brush. Then the pieces are clamped into a fixture for rapid, easy welding with an SWM-2 sigma hand-welding unit. A $^1/_{16}$-in. consumable electrode is supplied as a continuous coil of aluminum wire which is deposited as weld metal. High-quality butt, seam and fillet welds are made at speeds of 12 to 20-ipm.

Fig. 1 The easy-to-operate sigma hand torches produce high-quality welds at high speeds. They are ideal for welding hard-to-reach spots

Fig. 2 Note the aluminum coil which is fed automatically through the torch to the base metal. Because no flux is used, the welds are smooth and clean

Sigma welding offers definite and distinct advantages over the previous welding methods. Actual welding time is reduced by over 50%. With argon as the shielding gas, weld spatter is practically eliminated. No flux is needed so that finishing costs are kept to a minimum. Because of the high speed of sigma welding, little heat is absorbed by the base metal. This means that the distortion due to welding is substantially decreased.

Joining of Copper by Use of Heliwelding

by H. A. Huff, Jr.

COPPER has always presented a problem to the welder. It was one of the last metals to be welded successfully and its entire welding history in this country covers only about twenty-five years. This metal has peculiarities in its relations with oxygen and hydrogen which are further complicated by its high heat conductivity.

Most commercial copper, unless specially processed, contains oxygen in the form of cuprous oxides. These oxides, in wrought copper, are dispersed through the grains. Heated to a temperature around the melting point of the metal (1981° F), these oxides separate at the grain boundaries, causing a reduction in strength and ductility.

Hydrogen reduces the oxide under heat, forming steam. Since the hydrogen diffuses through the metal some fifteen times faster than steam, the steam does not escape as fast as it is formed and builds up enough internal pressure to rupture the metal along the grain boundaries, resulting in both embrittlement and danger of porosity when a weld is made.

With all coppers, the high heat conductivity of the metal means a long period of heating before fusion which adds to the chemical and metallurgical difficulties.

Heliwelding meets these two difficulties, chemical and physical, right at the root of the trouble. The intensely concentrated heat of the tungsten arc permits a minimum area and time of heating. This heat brings the metal to fusion quickly and is confined to a minimum amount of metal. The inert gas shield blocks the attack of oxygen and hydrogen in the weld area, permitting the copper to heat up, melt, flow together and freeze, free of any substantial change beyond that involved in recasting.

H. A. Huff, Jr., Air Reduction Sales, Co., New York, N. Y.

Photos courtesy Air Reduction Sales Co.

Figure 1

Within the normal limits of welding wrought materials, Heliwelding brings a new freedom and versatility to the welding of copper, making it easier, less costly and more certain to produce satisfactory results.

The case history of one shop is an excellent example of how the process works. On occasion this shop produces low-pressure tanks of the type and sizes used in domestic hot water heaters, fabricated from a tough pitch "lake" copper, without deoxidizer.

The cylinder walls of the tanks are 14-gage copper and the dished and flanged heads, from 14- to 10-gage material, thickening as the diameter of the tank increases.

The first lot of these tanks were welded by other methods and resulted in a high

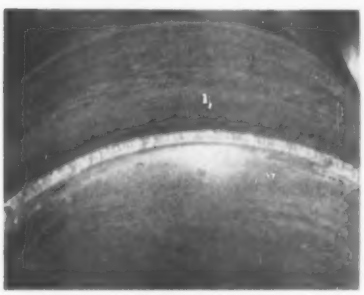


Figure 2

Figure 3

Figure 4

level of rejects because they would not stand the required 200 psi pressure test.

The switch to Heliwelding resulted in a highly satisfactory rate of production and quality of the welds, except in joining the plated steel fittings. For this work, the Heliweld process proved too hot and this minor problem was solved by using Sil-Fos applied with the oxy-acetylene torch.

The main problem was the welding of the lengthwise butt joint in the shell and the fillet weld on the lap between the shell and the flange of the head, as shown in Fig. 1.

Manual water-cooled Model 35 Heliweld Holders were the obvious method for this intermittent operation, with straight polarity d-c welding current and helium shielding gas. Shielding gas flow was set for 8 cfh per holder. Welding currents are 75–80 amp. for the 14-gage butt welds and 135–140 amp. for the fillet weld between the 14-gage shell and the 10-gage head. Tungsten electrodes of $^1/_8$-in. diam are used for the heavier currents and $^3/_{32}$ in. for the lower currents.

For welding, the shells are lined up and C-clamps attached to the ends of the joint. A simple rack holds the shell which is tacked every 10–12 in., before the clamps are removed and the butt joint is welded. No filler metal is used.

The heads are then put in place with the flange fitting inside the shell and a fillet weld (Fig. 2) is made between the end of the shell and the head.

Fittings are installed with Sil-Fos (Fig. 3) and the tanks are put under 200 psi air pressure with soap solution over all welds and joints, as shown in Fig. 4.

Heliwelding, in this case as in others has eliminated many difficulties involved in welding copper.

Unionmelt Welding Helps Move Mountains

AMERICAN machinery and know-how have acquired the reputation of being able to move mountains. This is literally true as is shown by the tremendous changes wrought on the earth's surface by our earth-moving equipment. Huge dams, vast airfields, broad highways and many other man-made wonders all over the world are proof of the efficiency of these heavy-duty machines.

Rubber-tired tractors manufactured by Caterpillar Tractor Co. are one of the most versatile prime-movers used in heavy construction work. Modern production methods are used to turn out these powerful tractors. One of the modern methods is Unionmelt welding. Wheel center disk assemblies are joined to rims to produce disk wheels by portable Unionmelt welding machines. This method produces a top quality welding job because of its high heat and deep penetration into base metal. Less rod metal is needed for a strong weld than with most electric welding methods.

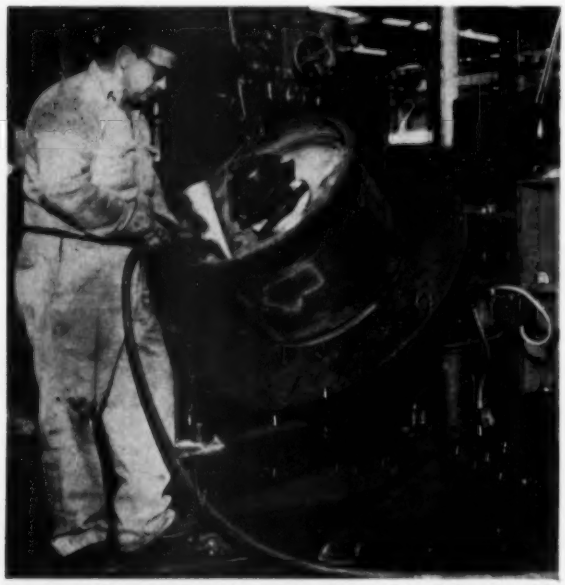


Fig. 1 High-speed welds are made on this disk assembly by a Unionmelt UW M-2 protable welding machine. As in all Unionmelt welding, these welds are protected from contamination by a blanket of granular welding composition

Fig. 2 Tough construction is needed on this tractor which powers a heavy-duty scraper. This equipment is being used here to cover a 155-acre pond at the site of the old Golden Cycle gold mine in Colorado Springs, Colo.

A rotating fixture turns the disk wheel assembly under the welding head. The flexible hose which feeds the welding rod enables the welding head to be moved wherever it is needed within a 20-ft radius of the machine controls. If welding is to be done further away, the entire machine can be picked up and carried.

These disk assemblies are fabricated from medium carbon steel of $^3/_8$ in. thickness. Welding speed is 20 ipm.

Opened to traffic last summer, the four-mile Chesapeake Bay Bridge permits Atlantic seaboard travelers to by-pass every large city from New York to Richmond. It represents man's most recent achievements toward overcoming attack by natural forces

Better Bridges By-Pass Tougher Traffic Tangles

Latest developments in man's historic effort to overcome transportation problems with spans that resist natures destructive forces

NATURE in building bridges, like the 90-ft span across Cedar Creek in Virginia, or the 261-ft natural bridge in southern Utah, failed to take into account the modern flow of traffic when she selected the site of her projects.

As the number of automobiles on the road has continued to increase, routing for the smooth flow of traffic has become more and more difficult. Often, building bridges to by-pass the worst traffic bottlenecks has proved the best solution.

But nature has taken a sullen attitude toward placing bridges where she herself did not see fit. At times she

Article prepared through the courtesy of the International Nickel Co.

High-Strength Bridge Steels

Name	*Carbon, max*	*Manganese*	*Nickel*	*Copper*	*Chromium*	*Molybdenum*	*Yield point, min 1000 psi*	*Tensile strength, min 1000 psi*
Cor-Ten	0.12	0.20–0.50	0.65 max	0.25–0.55	0.50–1.25	...	50	70
Hi-Steel	0.12	0.50–0.90	0.45–0.75	0.95–1.30	...	0.08–0.18	50	70
Tri-Ten	0.25	1.40 max	0.50–1.00	0.30–0.60	...	...	50	70
Mayari R	0.12	0.50–1.00	0.25–0.75	0.50–0.70	0.40–1.00	...	50	70
Yoloy	0.15	0.60 max	1.50–2.00	0.75–1.25	...	...	50	70
ASTM A8	0.43	0.80 max	3.0–4.0	0.20 min when specified	...	...	0.5 T. S.*	90–115

* Yield point is 0.5 of tensile strength or tensile strength of 45,000 to 57,000 psi.

releases floods, winds and ice floes against the man-made structures. Always they are under attack by heat, cold, corrosion, erosion and other weapons she commands.

Combatting these forces of nature—and at the same time placing bridges where they would be of the greatest service—has long taxed the ingenuity of man.

One of the most recent accomplishments in bridge building, which employs the latest in building materials and ranks high in solving traffic problems, is the Chesapeake Bay Bridge, linking the east-west shores of Maryland.

The 4-mile Chesapeake Bridge, opened for traffic last summer, makes it possible for the first time to by-pass every large city on the Atlantic seaboard from New York to Richmond. Not only can Philadelphia, Baltimore and Washington be avoided by through traffic, but these cities are made more accessible to people living on Maryland's Eastern shore (Delmarva Peninsula).

Builders of this and other bridges turned to various forms of protection for the structure. The protection that covers the concrete bridge piers at the water line, for instance, and the top flanges of the girders on the long spans are of "Mayari R" high-strength, low-alloy, chromium-nickel steel made by the Bethlehem Steel Co.

Courtesy, Wide World Photo

New York's Triborough Bridge is one of the busiest in the world. It is a connecting link between three of New York's five boroughs. A total of almost 870 tons of alloy steel went into its construction

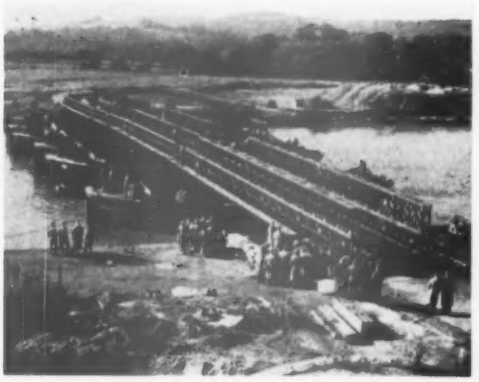
"Mayari R" was selected for the water-line plates of the Chesapeake Bridge because of its resistance to corrosion by salt atmosphere and because of its welding qualities, superior mechanical properties and low weight in proportion to its strength. It also has improved resistance to abrasion and impact in the as-rolled condition, and retains its toughness at low temperature.

Other recent structures using "Mayari R" include the Sunset Cliffs and Midway Drive bridges in San Diego and the Vermillion Street Bridge, Hastings, Minn. Older bridges containing a large amount of this material are the Eel River Bridge, Scotia, Calif., and the Triborough Bridge, New York City.

Fabrication by welding is becoming increasingly popular for bridge construction. The nickel-containing high-strength, low-alloy steels are particularly suited for this application as the yield strength is approximately 50% higher than that of structural carbon steel and there is little difference in weldability. In addition

Laying "Yoloy" grid flooring on Aiken Street Bridge, Lowell, Mass.

The main steel spans of the First Avenue Viaduct in Birmingham, Ala., are of "Cor-Ten" steel. Made with eight deck plate girders extending continuously over seven piers, this bridge spans Louisville and Nashville Railroad spur tracks. About 500 tons of "Cor-Ten" steel were used



Courtesy, Wide World Photo

Since the war the Bailey-type bridges, designed primarily for military purposes, have come into civilian use where a sturdy, easily constructed bridge is required. Both military and civilian units are shown above. Various alloy steels including "Cor-Ten," "Tri-Ten," "Yoloy" and "Mayari R" are used

to the Chesapeake Bay Bridge, such bridges as the Brooklyn-Queens Expressway and bridges on the New Jersey and Pennsylvania turnpikes are good examples of the use of welded high-strength, low-alloy nickel steels.

Another type of structural steel that has been in wide use for bridge construction is ASTM A8. This 3½% nickel structural steel has a long record of successful performance in bridges where it has been used in high-strength tension members and in large bolts.

Among the older bridges containing large tonnages of ASTM A8 steel are the Manhattan, Queensboro and George Washington bridges in New York; the North Wabash Avenue and West Madison Street bridges in Chicago; San Francisco's Oakland Bay Bridge and the Delaware River Bridge in Philadelphia.

Of the types of bridge construction which have been designed to meet various engineering problems, one of the most recent is the Bailey Bridge. This bridge, named for its British designer, Donald C. Bailey, came into wide use during World War II. Its purpose was to accommodate the heavy weight of modern war machines, and at the same time be of light enough material for assembly without the aid of heavy equipment. Today it is finding increasing use for civilian purposes.

The bridge is made from a number of interchangeable prefabricated parts, the chief component of which is a panel of light structural steel beams. The panels are an all-welded structure in the form of four "K's" facing alternate directions. These are linked together by simple pin joints and become the side girders.

The Bailey Bridge contains about 70% high-strength, low-alloy steel. Many of these steels have been used in constructing such bridges. In addition to "Mayari R," two United States Steel Co. products, "Cor-Ten" and "Tri-Ten," and the Youngstown Sheet and Tube Co.'s "Yoloy" have had wide use.

"Cor-Ten" has found many bridge applications. Among them are the Lawrence Avenue Grade Separation in Chicago, and the First Avenue Viaduct, Birmingham, Ala. The Marion Street Bridge, Salem, Ore., contains about 474 tons of "Tri-Ten" steel. Both the Lawrence Avenue, and the Marion Street Bridges were completed in 1952.

A frequent use of "Yoloy" steel in bridge construction is a grid-type flooring. Among the bridges which have the "Yoloy" flooring are the Franktown-Castle Rock Bridge in Colorado, and the Aiken Street Bridge in Lowell, Mass. The latter was built in 1951. "Yoloy" contains 1.50 to 2.0% nickel and 0.75 to 1.25% copper.

"Hi-Steel," a nickel, copper molybdenum high-strength, low-alloy steel, produced by the Inland Steel Co., is also used in bridge construction.

One outstanding feature common to all high-strength,

low-alloy steels is that paint applied to their surfaces is less inclined to suffer from attack by the elements. This quality is about 20% higher than that of other structural steels.

So man continues to progress in his historic effort to build bridges which can withstand nature's attacks more effectively, and to place them where they will be most useful in solving his problems of transportation.

Rotating Electrode

PRODUCTION is the mother of invention. A striking example of this is the new Ryan-designed rotatable electrode. Conceived by plant engineers as an accessory for large spot-welding machines, this special electrode was born from the necessity for speeding production of Ryan's huge external wing tanks.

Largest ever designed, the fuel cells are of spot-welded aluminum alloy construction. Not a rivet mars their sleek exterior. To speed production of these unusual tanks, Ryan production experts have installed tracked conveyor systems to eight large spot-welding machines.

By making the lower electrodes of these spot welders rotatable, it is possible for one man to push the tank sections between the 60-in. "jaws" of the big machines with ease. Without the retractable electrodes, it would require four men to lift the heavy, unwieldy tank sections over their interior bulkheads as the spot welding is shifted from one seam to another. Because of the massive bulk of the machines, it is not possible to employ an overhead crane system like that used to load the sections on the tracked dollies.

Operated by foot control, the rotatable electrode swings from a vertical to horizontal position to provide 10 in. of added clearance between the electrode arms. The movement is accomplished by a hydraulic cylinder and piston which pulls a yoke down. A pin in this yoke is keyed into an "L"-shaped slot in the lower electrode assembly. The copper electrode is mounted on a horizontal shaft which is firmly attached to the electrode arm. As the yoke descends, it rotates the electrode into a horizontal position.

In addition to the rotating movement, the electrode is actuated in another direction. The yoke is wedge-shaped, laterally, and moves in and out against steel roller bearings as it rotates the electrode. Thus, as the electrode moves into the upright position, the wedging action of the yoke pushes it tightly against the electrode arm to form a firm electrical contact.

Figure 1

Tests, made of this joint, show that it has a 100% electrical efficiency, equivalent to the current carrying efficiency of a one-piece electrode and arm assembly. This is an important advantage because 100,000 amp flow through this electrode. Even a slight resistance, caused by poor fit or faulty alignment, would seriously reduce this welding current.

With an eye on the practical aspects, Ryan tool designer H. F. Wallen designed the assembly so that it would operate on the same line water pressure which is used for cooling the electrodes. The hydraulic cylinder converts this 50 psi pressure into 400 psi which imparts a fast, positive action to the rotation of the electrode.

Stud Welding Used in Farm Machinery

FARM operators buying new model harvester-threshers are going to find replacement of worn rasp bars greatly simplified, thanks to a new method of installing them with stud-welded fasteners.

Adopted initially to increase production and eliminate troublesome problems in the assembly and balancing of rasp bar cylinders, the new technique employed by the International Harvester Co. at its East Moline, Ill., plant uses Nelson granular flux-filled studs in place of through-bolts on bars which were previously drilled and countersunk so that the heads would not project beyond the stripping surface.

A special five-gun Nelson Stud Welding production unit is used to end weld the ten threaded studs to the back of each McCormick rasp bar. Each stud is welded in a split second. The complete cycle, which includes loading studs into the welding guns, positioning the work and welding ten studs five at a time by shifting the rasp bar a total of 7 in. with an indexing device, takes less than 40 sec. A single operator turns out approximately 50 bars per hour.

The uniformity resulting from this controlled method of assembly has eliminated difficulties sometimes caused by variations in the pitch of the teeth and the danger that bolts, which were made to conform with the contour face, would turn to positions that interfered with smooth operation.

Other implement manufacturers, who are employing single and multiple gun Nelweld production units with special indexing fixtures for locating the required number of fasteners, enjoy the same basic advantages and have reported substantial production rate increases. One manufacturer, who uses eight studs per

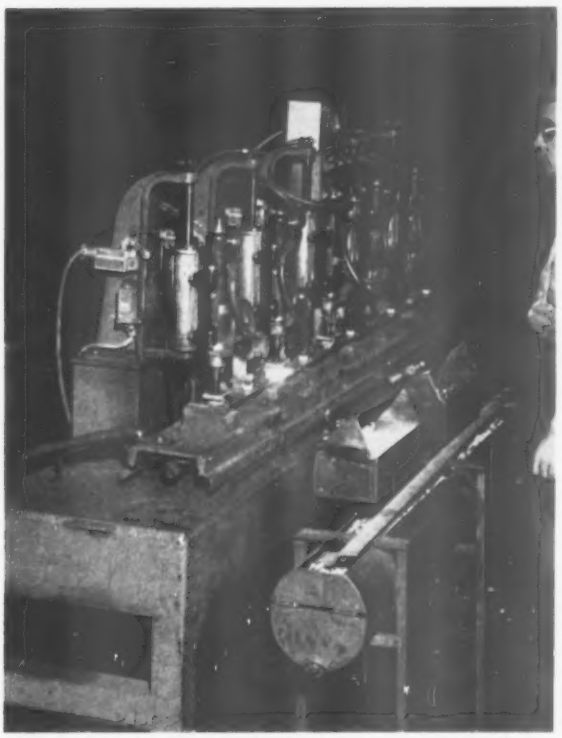


Fig. 1 This five-gun production unit used at the International Harvester Co.'s East Moline, Ill., plant is typical of production units developed to assist implement manufacturers in improving the quality and reducing production costs on harvester-threshers, corn-shelling and cotton-ginning equipment

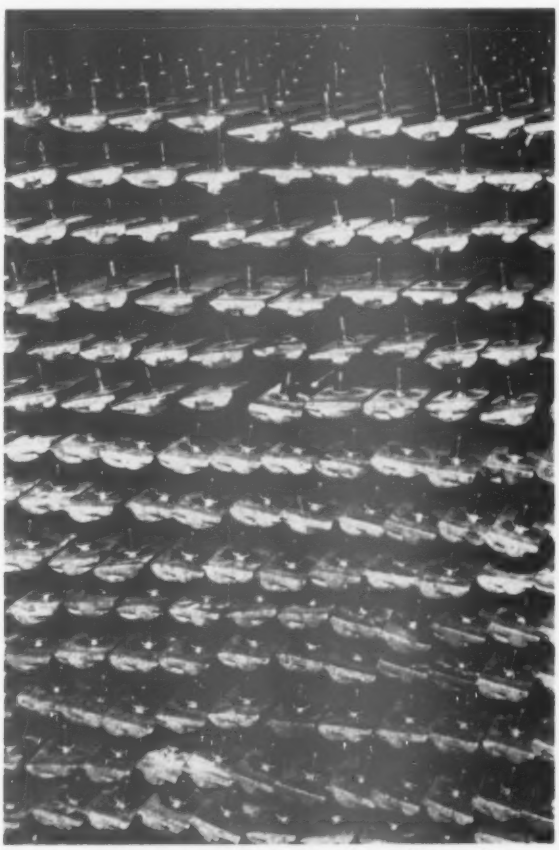


Fig. 2 The precision with which studs are fastened to rasp bars can be seen here, in a rack loaded with completed units. Note that wooden spacers are used in stacking to prevent damage to stud threads

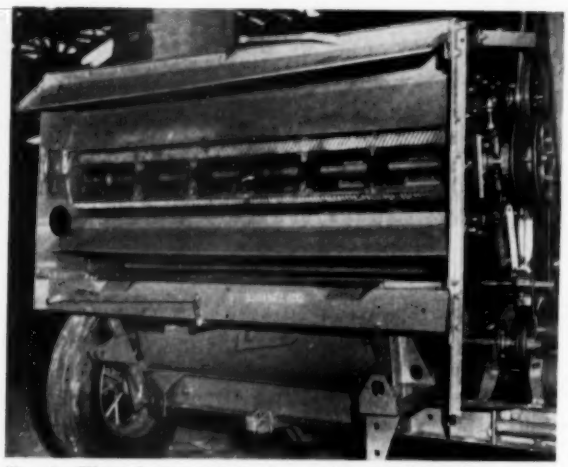


Fig. 3 This closeup of the front of a combined harvester-thresher separator unit with cover plate removed shows the stud-welded rasp bar cylinder assembly in place, with the reinforcing bars, to which they are attached, welded to the supporting disks. When the teeth on the rasp bars have been worn down, it is a simple matter to unscrew the nuts, which extend through the reinforcing bar behind the flange, and install new rasp bars

bar, and a multiple gun unit, reports an average production of approximately 400 rasp bars per man per day, as compared with a former rate of 100 per man per day when the bars were hand welded to the reinforcing bars.

Some implement manufacturers using both single-gun and multiple-gun Nelweld production units on rasp bars credit this equipment with dollar savings ranging from 75¢ to $1.54 per combine cylinder assembly. They report that shop balancing problems and the difficulties caused by variation in tooth pitch have been materially reduced or entirely eliminated.

The most important long-range benefits, however, are those accruing to their customers. Farm operators using the models on which stud welding has replaced hand welding will be able to replace rasp bar cylinder assemblies in the field and know that the assembly will be balanced properly. This has been almost impossible in the past, due to the difficulties in accurately controlling the distribution of weight on hand-welded replacement bars and back-up plates. Furthermore, maintenance costs will be reduced since the stud-welded rasp bars can be removed from the original reinforcing bars (back-up plates). Removal and replacement of bars is further simplified since the studs are permanently attached to the bars and it is impossible for the head to turn should the nut be rusted or fouled in any way.

Protect the Part During Welding

by E. E. Olson

ON MANY welding jobs some sections of the part need to be protected against the heat of your blowpipe. On other jobs, sections must be rebuilt to specific contours or dimensions. Fire-resistant carbon products are virtually the only materials that are completely satisfactory for these purposes. Carbon does not shrink or crack when heated, and does not stick to metal. That is why carbon is so widely used as a welding aid.

Many forms of carbon are available. Carbon paste possesses all of the molding qualities of plaster of paris, clay or other molding substances with the added fire-resistant qualities of carbon. In solid form, carbon can be machined to practically any shape desired.

Some uses for carbon paste in welding are to protect a threaded or irregularly shaped hole near the break to be welded and to prevent distortion of a part due to excess heat. Solid carbon can be threaded to fit a threaded hole which has broken. Such a carbon bolt will act as a mold for rebuilding the threaded hole. Carbon in bar shape forms a mold for rebuilding a plain hole in the same way.

One job that illustrates the value of carbon in welding, involved rebuilding a missing piece on the cast-iron support for a drill press table. This missing triangle, measuring about 2 in. wide and 4 in. long, extended into a threaded hole near the center of the casting. Missing metal had to be replaced without filling in this hole or disturbing the alignment of the part.

The bore of this casting was filled with a preshaped carbon bar, machined to fit. Metal from a cast-iron welding rod was then flowed on the casting and fused completely with the base metal. Very little finishing work was required on this repair since the contour of the new section was so nearly perfect. After cooling, the carbon bar was easily removed and the hole in top was drilled and tapped.

E. E. Olson, Linde Air Products Co., Seattle Wash.

Fig. 1 This cast-iron part was rebuilt without disturbing the alignment or filling in the bore with weld metal

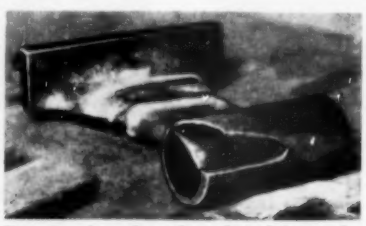


Fig. 2 A carbon bar fitted into the casting bore provides a foundation for buildup with cast-iron welding rod

Fig. 3 Little finish machining was needed on this repair because carbon protected sound metal and molded the rod deposit

the AMERICAN WELDING SOCIETY

activities • related events

New Sustaining Member

Pennsylvania Transformer Co., a McGraw Electric Co. Division, Adams Ave., P. O. Box 330, Canonsburg, Pa., Greater Pittsburgh District.

Facilities of the company are devoted exclusively to designing and manufacturing a complete line of electrical transformers. This includes distribution transformers, 3 kva through 500 kva, up to 67,000 v.; and power transformers, 750 to 250,000 kva, in voltage classes up to 330,000 v.

Pennsylvania does all its design and manufacturing work at its modern one-floor, 600,000 sq-ft plant. This includes electrical and mechanical design; coil winding; core building; fabrication of covers, bases, structural pieces, core frames; painting; assembling; testing, etc.

Included among the types of transformers manufactured by Pennsylvania Transformer are furnace transformers, load ratio control transformers, unit substation transformers, subway transformers, dry type transformers and step voltage regulators.

Steve Darko—Sustaining (A) Member Representative.

1953 Year Book

In future years the SOCIETY will publish its Year Book in various sections, loose leaf form. Each section will treat specifically with one of the Year Book's present departments in view of the fact that the data for each of these departments are available at different times of the calendar year and if the whole awaits the binding in one volume, much of the information is outdated and of little value to interested parties.

Sections of the Year Book which will be available to members of the SOCIETY on *Aug. 1, 1953* are:

Section 1—Officers and Standing Committees
Section 2—Finance and Membership Recapitulation
Section 3—Technical Activities
Section 5—Rules for Awards, Committees and Activities

Section 4, not mentioned above, will be a listing of the SOCIETY's Constitution and its By-Laws. The present By-Laws are being revised to include the various Rulings of the Board of Directors during a number of years past. Upon completion of revision the By-Laws shall be submitted to the Board of Directors and the Membership for approval. Then, after approval, Section 4 shall be available to Members upon request.

Section 6 to be prepared very soon, will provide an annotated descriptive listing of the SOCIETY's Codes, Standards, Specifications and Publications.

Section 7 will be prepared later this year. It will treat with the general operation, benefits of membership and other data concerning our SOCIETY.

For those members interested in receiving copies of available sections (Aug. 1, 1953), kindly send request to AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y., *specifying desired sections.*

Section Annual Reports

Each year the SOCIETY sends to all of the Section Secretaries, forms for the Annual Reports of the Sections. A report from each Section is a By-Law requirement of the SOCIETY and therefore a required activity of the Section.

The report is made out in such form that most of the work is already done other than filling in the answers to questions and the names and addresses of the Section Officers. From the list of newly elected Officers that the Sections provide in their annual reports, the National Headquarters prepares a list of Section Officers (Chairmen and Secretaries) with the meeting dates and issues this list to each Section Secretary.

Unless the Sections respond to this request promptly, it is impossible for National Headquarters to provide such information to all other Sections.

There is real value in all Sections knowing the dates of other Sections' meetings as scheduled, as well as the names of the managing officers—the Chairman and the Secretaries. Visiting National and District Officers need this material so that when possible they may arrange their business schedules to tie in with the Section meeting.

Therefore, each Section is urged to provide their annual report as quickly as possible. When the report is not received by the deadline date, July 15th, Sections not responding risk the possibility of the Section Officer Directory being issued without up-to-date information regarding their Officers and activities.

One copy of the report should be sent to National Headquarters, one copy to the Section's District Vice-President and one copy retained by the Section for its records.

Speakers' and Motion Pictures Lists

Last summer (1952) all Section Chairmen and Secretaries were issued an AWS Official Speakers' Directory. The issuing date was June 15th. Two months later all Chairmen and Secretaries received an AWS Official Motion Picture Directory, of which the issuing date was August 15th.

Those Directories should be turned over by the outgoing Chairmen and Secretaries to the incoming officers taking those positions. We frequently receive requests from the new officers asking if we do not have such material, indicating that the outgoing officers have not released their files completely to their successors.

Each year, starting along about January, which is as early as we can logically start considering industrial changes on the basis of a calendar year, the SOCIETY requests the allied industry to provide the names of speakers and their subjects for listing in the Speakers' Directory, as well as motion pictures they may have available. Special forms are provided with the letter to industry making it easy for them to fill in the required data. They are told that the speakers must be available for scheduled appearances as arranged between the AWS Sections and the Speakers, at Section meetings during the succeeding year. Greater difficulty is encountered in receiving an adequate number of replies than would be expected. For example, even though approached the first of the year, we have had to send out a follow-up letter to a large proportion of the industry asking them, this year, to please reply to our initial communica-

(Continued on page 676)

Tentative Program

AWS National Fall Meeting

Hotel Cleveland—Cleveland, Ohio

Week of Oct. 19, 1953

MONDAY MORNING, OCTOBER 19th

A—PRIZE AWARDS AND ADAMS LECTURE

Chairman—F. L. PLUMMER, *President*, American Welding Society
Co-Chairman—H. C. BOARDMAN, *Chairman*, National Program Committee

Aspects of Welding Research in British Merchant Shipbuilding
by R. B. Shepheard, The Shipbuilding Conference

MONDAY AFTERNOON, OCTOBER 19th

Two Simultaneous Sessions

B—GOUGING AND CUTTING

Chairman—RICHARD L. DEILY, Air Reduction Sales Co.

Co-Chairman—R. S. BABCOCK, Linde Air Products Co.

1. **The Arcair Process**
by MYRON D. STEPATH, Arcair Co.
2. **Shielded Metal-Arc Cutting and Grooving**
by HELMUT THIELSCH and J. QUAAS, Eutectic Welding Alloys Corp.
3. **Advanced Automatic Flame Cutting for Machinery Weldments**
by HOWARD B. CARY, Marion Power Shovel Co.

C—RESISTANCE WELDING

Chairman—R. E. POWELL, Western Electric Co.

Co-Chairman—JOHN DIEBOLD, Diebold Engineering Sales Co.

1. **Radiography of Spot Welds**
by ROBERT C. McMASTER, Battelle Memorial Institute
2. **Resistance Welding in Jet Engine Manufacturing**
by FRANK J. WALLACE, Pratt and Whitney Aircraft Div. of UAC
3. **A Study of the Cooling Rates in Flash Welds in Steel**
by ERNEST F. NIPPES, WARREN F. SAVAGE and GORDON GROTKE, Rensselaer Polytechnic Institute
4. **Some Applications of High-Speed Motion Picture Photography to Resistance Welding**
by I. S. GOODMAN, Westinghouse Electric Corp.

MONDAY EVENING, OCTOBER 19th

Ball Room

President's Reception

National Officers Dinner

TUESDAY MORNING, OCTOBER 20th

Three Simultaneous Sessions

A—STAINLESS STEEL

Chairman—F. W. DAVIS, U. S. Atomic Energy Commission

Co-Chairman—V. N. KRIVOBOK, The International Nickel Co.

1. **Effect of Various Heat Treatments on Modified 347 Weld Deposits**
by R. D. THOMAS, JR., and LORIN K. POOLE, Arcos Corp.
2. **Silver Brazing Alloys for Corrosion-Resistant Joints in Stainless Steels**
by GEORGE H. SISTARE, Handy & Harman, L. H. GRENELL, General Motors, and JOHN J. HALBIG, Armco Steel Corp.
3. **Submerged Arc Welding of Chromium Bearing Steels**
by CLARENCE E. JACKSON and ARTHUR E. SHRUBSALL, Union Carbide & Carbon Laboratories

B—TITANIUM

Chairman—F. R. HENSEL, P. R. Mallory & Co.

Co-Chairman—G. GRABLE, Battelle Memorial Institute

1. **Tension, Shear and Impact Strengths of Spot-Welded Titanium Joints**
by M. L. BEGEMAN, E. H. BLOCK, JR., and FRANK W. McBEE, JR., University of Texas
2. **Fusion Welding Commercially Pure Titanium**
by FRANCIS H. STEVENSON, Aerojet General Corp.
3. **Alloy Filler Metals in Commercially Pure Titanium**
by CARL E. HARTBOWER, Watertown Arsenal Laboratory

Welding and Cutting Exhibits and Demonstrations

NATIONAL METALS EXPOSITION

Public Auditorium

Cleveland, Ohio

HOURS OF THE EXPOSITION

Monday, Tuesday and Wednesday—
October 19th, 20th and 21st
12 Noon to 10:30 P.M.

Thursday and Friday—
October 22nd and 23rd
10:00 A.M. to 6:00 P.M.

Admission by special invitation or by AWS registration badge or membership card of any participating society.

BE SURE TO VISIT THE EXPOSITION

Everyone interested in welding should visit the 35th National Metals Exposition at The Public Auditorium. There will be hundreds of displays, many featuring welding and the allied processes and others featuring metals, processes and metal-working equipment. The Exposition is sponsored by the American Welding Society, American Society for Metals, the Metals Branch of AIME, and the Society for Non-Destructive Testing.

C—STRUCTURAL

Chairman—BRUCE G. JOHNSTON, University of Michigan

Co-Chairman—ROSS YARROW, Consolidated Iron & Steel Co.

1. **Residual Stress and Inelastic Bending of WF Columns**
by ROBERT L. KETTER, LYNN S. BEEDLE, Lehigh University, and E. L. KAMINSKY, David Taylor Model Basin
2. **Weldability of Structural Steel Discussed from the Viewpoint of Federal Agencies**
by E. L. ERICKSON, Chief, Bridge Branch, Bureau of Public Roads
3. **Development of Welded Bridge Construction**
by N. W. MORGAN, Principal Highway Bridge Engineer, Bureau of Public Roads
4. **Recent Applications of Welded Design to Industrial Building Framings**
by A. AMIRIKIAN and E. G. ODLEY, Bureau of Yards and Docks, Navy Department

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TUESDAY AFTERNOON, OCTOBER 20th

Two Simultaneous Sessions

D—ALUMINUM AND AIRCRAFT

Chairman—R. S. GREEN, Ohio State University

Co-Chairman—CHARLES BRUNO, Reynolds Metals Co.

1. **Soldering of Aluminum**
   by JAMES D. DOWD, Aluminum Company of America
2. **Fatigue Strength of Welded Butt Joints in 3/8-In. Thick Aluminum Alloy Plates**
   by E. C. HARTMANN, MARSHALL HOLT and I. D. EATON, Aluminum Company of America
3. **Some Considerations on Weldability of Aluminum Alloys**
   by J. KOZIARSKI, Piasecki Helicopter Corp.

E—WELDABILITY

Chairman—R. E. SOMERS, Bethlehem Steel Co.

Co-Chairman—J. ROBERT HENRY, Cleveland Diesel Div., General Motors Corp.

1. **Cracking in High-Temperature Alloys as Related to Microstructure**
   W. R. APBLETT and W. S. PELLINI, Naval Research Laboratory
2. **Ductility Transition Characteristics of Weld Metal**
   by EARL ESCHBACHER and W. S. PELLINI, Naval Research Laboratory
3. **Further Studies on Weld-Metal Microcracking in Mild Steel**
   by A. E. FLANIGAN, University of California

Plant Visits

Members visiting Cleveland will be given an opportunity to choose between two plant visits, one to the Cleveland Tank Plant of Cadillac Motor Car Division, GMC, and the other to the Euclid Road Machinery Co.

The visit to the Cleveland Tank Plant of the Cadillac Motor Car Division requires visitors to have proof of American Citizenship and limited to 75 persons.

The visit to the Euclid Road Machinery Co. is open to all.

Further information as to time and cost of transportation will be given in the later edition of the program.

WEDNESDAY MORNING, OCTOBER 21st

Three Simultaneous Sessions

A—WELDABILITY

Chairman—L. C. BIBBER, United States Steel Co.

Co-Chairman—G. E. CLAUSSEN, Union Carbide & Carbon Research Laboratories, Inc.

1. **Army First Pass Groove Weld Crack Susceptibility Test**
   by Z. J. FABRYKOWSKI, S. GOODMAN and B. A. SCHEVO, Detroit Arsenal
2. **Low-Temperature Bend-Test Properties of Bead-on-Plate Welds**
   by L. A. HARRIS, R. B. MATTHIESEN and N. M. NEWMARK, University of Illinois
3. **Fatigue Properties of Weld Metal**
   by L. A. HARRIS, R. B. MATTHIESEN and N. M. NEWMARK, University of Illinois

B—TITANIUM

Chairman—COL. B. S. MESICK, Ordnance Corps, Watertown Arsenal

Co-Chairman—W. L. WARNER, Watertown Arsenal

1. **A Study of the Weld Heat-Affected Zones in Titanium Alloys**
   by ERNEST F. NIPPES, JOHN M. GERKEN and BERNARD W. SCHAAF, Rensselaer Polytechnic Institute
2. **Welding Characteristics of Titanium and Titanium Alloys**
   by MARIO L. OCHIEANO, Lockheed Aircraft Corp.
3. **Study of the Effects of Alloying Elements on the Weldability of Titanium Sheet**
   by DR. MAX HANSEN, Armour Research Foundation

C—CONTROLS AND INSPECTION

Chairman—GILBERT S. SCHALLER, University of Washington

Co-Chairman—R. J. KRIZ, The James B. Herron Co.

1. **Inspection Techniques for Quality Welding Production**
   by LEW GILBERT, *Industry and Welding*, and WILLIAM B. BUNN, The M. W. Kellogg Co.
2. **Nondestructive Testing as an Aid to the Increased Use of Welding for Steel Structures**
   by LLOYD J. OYE, Magnaflux Corp.
3. **Tolerances on Fillet Welds**
   by JOHN MIKULAK, and MERLE B. DILLMAN, Worthington Corp.

WEDNESDAY AFTERNOON, OCTOBER 21st

Three Simultaneous Sessions

D—PIPE

Chairman—A. J. ERLACHER, United Engineers & Constructors, Inc.

Co-Chairman—N. C. JESSEN, Babcock & Wilcox

1. **Further Studies of the Arc Welding of Low-Chromium Molybdenum Steel Pipe**
   by J. BLAND, Standard Oil Co. (Ind.)
2. **Superheaters for 1100° to 1500° F Test Installation**
   by BELA RONAY and W. E. CLAUTICE, U. S. Naval Engineering Experiment Station
3. **Carbide Segregation and Decarburization at Welded Joints**
   by I. A. ROHRIG, Detroit Edison Co. and H. S. BLUMBERG, M. W. Kellogg Co.

E—RESEARCH

Chairman—G. E. DOAN, Koppers Co., Inc.

Co-Chairman—FRANK FLOCKE, The Thornton Co.

1. **Welding Metallurgy of Nodular Cast Iron**
   by EDWARD E. HUCKE and PROF. H. UDIN, Massachusetts Institute of Technology
2. **The Effect of Low-Temperature Stress Relieving on Stress-Corrosion Cracking of Mild Steel**
   by C. R. McKINSEY, Union Carbide and Carbon Research Laboratories, Inc.
3. **Transformation of Cr-Mo Steels During Welding**
   by W. R. APBLETT, JR., R. P. DUNPHY and W. S. PELLINI, Naval Research Laboratory
4. **Multiple Contact Resistance**
   by W. B. KOUWENHOVEN and DONALD R. HAGNER, The Johns Hopkins University

F—EDUCATION

Chairman—DEAN A. POTTER, Purdue University

Co-Chairman—PROF. M. L. BEGEMAN, University of Texas

1. **Teaching Engineering Fundamentals**—DEAN S. C. HOLLISTER, Cornell University
   Discussion: DEAN W. B. KOUWENHOVEN, The Johns Hopkins University; PROF. R. S. GREEN, Ohio State University
2. **Teaching Welding Design**—DR. J. P. VIDOSIC

WEDNESDAY EVENING, OCTOBER 21st

Section Officers Dinner

WRC University Dinner and Conference

THURSDAY MORNING, OCTOBER 22nd

Three Simultaneous Sessions

A—PRESSURE VESSELS AND RESEARCH

Chairman—T. N. ARMSTRONG, The International Nickel Co., Inc.

Co-Chairman—L. J. LARSON, Allis-Chalmers Manufacturing Co.

1. **Plastic Fatigue Strength of Pressure Vessel Steels**
   by ROBERT D. STOUT, JOHN H. GROSS and D. E. GUCER, Lehigh University
2. **A Qualitative Study of Residual Stresses in Welds by Photoelasticity**
   by DR. MELVIN MARK, Raytheon Manufacturing Co.
3. **Effect of Nitrogen and Carbon Dioxide Atmospheres on Arc Welding**
   by PROFS. SOWA, TRUCKENMILLER and WAGNER, University of Michigan
4. **Biaxial Fatigue Properties of Pressure-Vessel Steels**
   by T. J. DOLAN and C. E. BOWMAN, University of Illinois

B—INERT ARC WELDING

Chairman—C. I. MacGUFFIE, General Electric Co.

Co-Chairman—H. E. ROCKEFELLER, Linde Air Products Co.

1. **Inert-Gas-Shielded Metal-Arc Welding of Low-Carbon Steels**
   by GEO. C. CHRISTOPHER and R. C. BECKER, International Harvester Co.
2. **Characteristics of Consumable-Electrode Inert Arcs**
   by R. W. TUTHILL, General Electric Co.
3. **Effect of Power Supply Characteristics on Sigma Welding**
   by W. H. HELMBRECHT, and R. L. HACKMAN, Linde Air Products Co.
4. **Weld Properties of a Carbon-Steel Electrode for Use with Inert Gas Shields**
   by HARRY C. COOK and GILBERT R. ROTHSCHILD, Air Reduction Research Laboratories

C—AUTOMATIC ARC

Chairman—C. C. PECK, Cecil C. Peck Co.

Co-Chairman—L. S. McPHEE, Whiting Corp.

1. **New Developments in Fluxes for Automatic Welding and Hard Surfacing**
   by L. K. STRINGHAM, Lincoln Electric Co.
2. **Multiple Electrode Welding by the Unionmelt Process**
   by D. E. KNIGHT, Linde Air Products Co.
3. **Multiple-Arc Submerged Arc Welding**
   by THEODORE ASHTON, Lincoln Electric Co.

THURSDAY AFTERNOON, OCTOBER 22nd

Board of Directors Meeting
Annual Business Meeting

THURSDAY EVENING, OCTOBER 22nd

Annual Dinner

FRIDAY MORNING, OCTOBER 23rd

Three Simultaneous Sessions

A—APPLICATIONS

Chairman—C. B. HERRICK, C. B. Herrick Co.

Co-Chairman—L. P. ELLY, Bethlehem Steel Co.

1. **New Welding Shop Facilities, Methods and Equipment at the Whiting Refinery**
   by RAY M. KOLB and R. C. WHEELER, Standard Oil Co. (Ind.)
2. **Silver and Gold for Brazing Electronic Components**
   by A. W. SWIFT and R. J. METZLER, Handy & Harman
3. **New Results in Tool and Die Welding**
   by ROBERT H. GROMAN, Eutectic Welding Alloys Corp.
4. **Austenitic Manganese Steel Welding Electrodes**
   by HOWARD S. AVERY and HENRY J. CHAPIN, American Brake Shoe Co.

B—INERT ARC WELDING

Chairman—R. M. WILSON, International Nickel Co.

Co-Chairman—A. B. LYTLE, Electro Metallurgical Co.

1. **A New Method to Prevent Rectification of Current and High-Frequency Interference in Inert-Gas Arc Welding**
   by JOHN MURRAY, Lincoln Electric Co.
2. **New Developments in Sigma Welding of Carbon Steel**
   by T. McELRATH, JR., and R. T. TELFORD, Linde Air Products Co.
3. **Porosity in the Welding of Carbon Steel**
   by GLENN W. OYLER and ROBERT D. STOUT, Lehigh University

C—FIELD-ERECTED STRUCTURES

Chairman—E. MacCUTCHEON, Bureau of Ships, U. S. Navy

Co-Chairman—L. C. McNUTT, United Engineers & Constructors, Inc.

1. **Scale Effects in Notch Brittleness**
   by YOSHIO AKITA, Transportation Technical Research Institute
2. **Effect of Subcritical Heat Treatment on the Transition Temperature of a Ship Plate Steel**
   by E. B. EVANS and L. J. KLINGLER, Case Institute of Technology
3. **Welded Mexican Bridge**
   by THOMAS C. KAVANAGH, New York University

NEWS OF THE INDUSTRY

New Hobart Welding Electrode Plant

Hobart Brothers Co.'s new $2,000,000 electrode plant in Troy, Ohio, is more than a sleek modern building. It is a symbol of the company's faith in the future of welding.

This new electrode plant is now in full production. Facilities include shipping and receiving docks for both rail and truck transportation, unique chemical and wire storage facilities, production, quality control, testing, research, and experimental departments. The ovens are the most modern and scientifically designed to automatically control the moisture content of the electrodes produced.

The building is of steel and masonry construction. Walls are constructed so that when expansion is required a specific wall may be removed to make room for extension.

General Electric's Welding Department Transferred to York, Pa.

The General Electric Co.'s Welding Department located in Fitchburg, Mass., since 1946, will be transferred to York, Pa., by the end of March 1954, R. C. Freeman, general manager of the department, announced recently.

He explained that the planned transfer will enable the Welding Department, and the company's Small Turbine and Supercharger Department which will remain in Fitchburg, to expand and thereby provide room for predicted increases in the business of both departments.

The Welding Department is scheduled to move into a newly vacated company plant at York, which will allow room for necessary manufacturing expansion. The plant formerly housed G-E's Wire and Cable Division, which is being moved to two New England cities.

Mr. Freeman explained that General Electric's Fitchburg operation had reached its capacity with respect to the possible further expansion of the Welding Department's manufacturing facilities. When there are several G-E operations in the same plant and more space is needed, which is the case in Fitchburg, the tendency is to transfer the smallest or least compatible part of the operation to another city, making space available for local operation of the principal process or line of compatible products.

The Welding Department, according to Mr. Freeman, is in the process of following through on a three-point program of reorganization, namely that of standardization, integration and mechanization of the department's entire operations. In the past, he said, many of the component parts of G-E welding equipment have been produced by outside vendors. Utilizing the resources of the York plant, G-E hopes to perform more manufacturing functions than were heretofore possible.

In choosing the York site, more than 53 cities were considered. York was selected because of its close proximity to the center of the welding markets, its nearness to the Welding Department's source of raw materials and the fact that an existing G-E plant of desirable size was being vacated at approximately the same time.

C. I. MacGuffie, G-E Welding Department manager of marketing, commenting on the new move, stated that G-E welding customers will receive better service because of the increased and more effective methods of distribution from the York plant. He stated that 70% of all welding industry business exists in a belt extending from Chicago, Ill., to New York City, the area in which the new G-E plant will be located. Mr. MacGuffie said that although the manufacturing facilities of the department will be somewhat curtailed during the move to the "new home," plans have been made whereby a large inventory of equipment will be stock-piled to serve as a reserve during the transfer period.

New Main Plant—Magnaflux Corp.

A new step in the growth of small private industry was noted in May, in the opening of a newly built main plant by Magnaflux Corp., at 7300 Lawrence Ave., Chicago, Ill. This company has pioneered the special field of testing for defects over nearly 25 years. It started with two men with an idea and grew because the company could develop and supply needed inspection methods and equipment to American manufacturing and transportation industries, and to the armed forces in times of national need. The purpose of this inspection is to assure reliable equipment free from unseen defects, its manufacture at lower cost and its reliable operation after overhaul.

The new plant and main office building comprises 74,000 sq ft, nearly twice the size of the old plant used for 13 years at 5900 Northwest Highway, Chicago. Of recent years, and especially since Korea, the old plant restrictions have required branch plant operations by Magnaflux, and certain subcontracting. The operations are now all combined under one roof at this new location, with increased efficiency. The plant site is an area of 9 acres, allowing room for future growth.

The company grew from its beginning in 1929, when Alfred Victor de Forest developed the Magnaflux method of inspection. To further develop and promote the method, he formed a partnership with F. B. Doane in Pittsburgh who is now President. The young enterprise had no capital, just the idea that here was a better method of testing than was then available. That their faith in the future of the method was sound is demonstrated by the success of the venture.

Starting with its Magnaflux, for inspection of magnetic parts, the company has developed and encouraged intelligent use of Zyglo for nonmagnetic metals, and other newer methods now widely used on glass, ceramics, unfired clay ware and powdered metal compacts. Their brittle coatings for effective stress analysis and for design development have grown to wide use, as have newer ultrasonic and electronic testing tools to measure thicknesses of metals from one side, to measure hardness and alloy by noncontact conductivity tests, and other special numerous tests for use by all types of industry.

Movie on Aronson Positioners

Aronson Machine Co., Arcade, N. Y., announces the availability of a 450-ft movie on Aronson Universal Balanced Positioners. This unique, patented positioner is illustrated as a comparison with other positioners and other methods of positioning work from a time-saving and improved workmanship basis.

There are many weldments being positioned by use of: Chain Fall manually; Chain Fall electrically; pushing around on the floor manually; positioned in a gear-driven positioner; and finally positioned on an Aronson Universal Balanced Positioner. During this sequence, time studies are made and the bold facts prove Aronson Universal Balanced Positioning saves time, allows better workmanship, reduces operator fatigue.

The movie is available to larger plants primarily but will be shown to any number of smaller groups by Aronson Machine Co. personnel upon appointment.

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This new tungsten-zirconium alloy self cleans contamination without loss of electrode. Lasts far longer than ordinary rods and assures sound dependable welds every time.

Zirtung operates on the same current range as thoriated tungsten. Contains no radio-active material. Wonderful for welding stainless and mild steels, aluminum, and magnesium. For further details, call your nearest Sylvania Welding Distributor or write to: Sylvania Electric Products Inc., Dept. 3T-4907, 1740 Broadway, New York 19, N. Y.

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Welding Session During AIEE Summer Meeting

Some of the questions raised in the welding industry concerning the use of electric power were answered here on Tuesday, June 16th, when a session of the Summer General Meeting of the American Institute of Electrical Engineers was devoted to "Utility charges for Service to Resistance Welders." The session was one of 54 of a wide variety on electrical engineering in many of its ramifications in industry and science which was held during the 5-day meeting June 15–19th, inclusive, under the sponsorship of the Philadelphia Section of the Institute.

Papers presented during the welding session are: "Fundamentals of Electric Rate Making," by L. R. Lefferson, Ebasco Services, Inc.; "Utility Metering on Resistance Welding Loads," by M. A. Faucett, University of Illinois; "Why Special Utility Charges for Resistance Welders?"; "A High Output-Low Demand Resistance Welding Machine," by R. S. Phair, the Budd Co., and "Design Transformers for Resistance Welding Machines," by D. L. Knight, National Electric Welding Machines Co.

The meeting was held at the Chalfonte-Haddon Hall.

National Technical Committees to Be Established by American Bureau of Shipping

During the course of his recent visit to European offices of the American Bureau of Shipping, including those in Italy, Greece, Turkey, France, Belgium, Holland, Germany and the United Kingdom, Walter L. Green, President and Chairman of the Board, thoroughly investigated the problem of adjusting the Bureau's Rules for Building and Classing of Steel Vessels to meet adequately the minor differences which exist between the Bureau's specific requirements and the needs of the various localities.

These occur due to differences in national codes as well as variance in steelmaking procedures and specifications, local differences in shipbuilding practice and in the nature of the shipping trades themselves.

Such differences have existed in the United States in various sections of the country for many years. These problems have been successfully met in the past by the American Bureau of Shipping through the medium of its system of Technical Committees. Thus the Bureau long ago established the Great Lakes Technical Committee and the Western Rivers Technical Committee to work within the structure and review of its Technical Committee and the Committee on Naval Architecture and the Committee on Engineering. The system has worked most successfully and has resulted in satisfaction to the local groups whose problems appear to justify special treatment. It has at the same time upheld and strengthened the technical standards and efficiency of the Bureau's Rules.

The Bureau has therefore decided to establish from time to time as experience proves advisable, Technical Committees for countries outside of the continental borders of the United States. These Committees would actively consider and, at suitable intervals, recommend to the Bureau's Technical Committees such amendments to the Rules as may be deemed necessary and advisable. These Committees would likewise be given full opportunity to consider and make recommendations respecting the additions to, alterations and development of the Rules for Building and Classing of Steel Vessels, which it is the Bureau's custom to revise and publish annually.

It is the Bureau's opinion that this course of action will result not only in simpler and more logical resolution of the problems its Technical and Surveying Staff meet in shipping centers of the world, but will result in a general strengthening of its Rules and its technical thinking by the contributions which will certainly be made by the committees functioning in the countries outside of the United States.

Metal and Thermit Distributors

Metal and Thermit Corp., New York, N. Y., announces the appointment of nine new distributors for their line of Murex Electrodes, M&T Welding Machines and Accessories. Their distributors now number more than 250 throughout the country.

The new distributors are Alaska Welding Supplies, Inc., Anchorage, Alaska; Auto Gas Light & Appliance Co., North Bergen, N. J.; Butler Gas Co., New Brighton, Pa.; Fidelity Sales, Newark, N. J.; Littrell Parts Co., Inc., Redding, Calif.; McKinney Welding Supply, New York, N. Y.; Merritt-Holland Supply Co., Wilmington, N. C.; San Antonio Machine & Supply Co., San Antonio, Tex., and Lee T. Staton, Riverdale, N. J.

Seven Distributors Added by Alloy Rods Co.

Continuing its policy of expanding its national distributor organization in order to serve the trade better, Alloy Rods Co., York, Pa., leading manufacturer of alloy arc-welding electrodes, has just added seven more welding supply companies to its distributor roster, according to E. R. Walsh III, general sales manager.

Alloy Rods Co. arc-welding electrodes are now being distributed by Massey Auto Parts, Brownwood, Tex.; Heidt Equip-

ment Co., Oakland, Calif.; Rene Neveu & Son, Plattsburg, N. Y.; Welders Supply Co., Portland, Ore; Lone Star Welding Supply, San Antonio, Tex.; General Engineering & Machine Co., Tampa, Fla., and Dunlap Welding & Supply Co., Zanesville, Ohio.

Eutectic Forms Canadian Co.

The increased Canadian demand for the very popular products manufactured by the Eutectic Welding Alloys Corp., Flushing, N. Y., has made necessary the formation of a Canadian company to provide the service facilities such constant development requires. The new company will be known as The Eutectic Welding Alloys Co. of Canada, Ltd.

L. D. Richardson, AWS, Divisional Sales Manager, has been promoted and in addition to his Divisional duties will act as General Canadian Sales Supervisor. Michael Doody, who has represented the company in Eastern Canada, will supervise the organization in Ontario, Quebec and the Maritimes. These men are both well known in Canadian welding circles and have lectured on many occasions at Canadian Technical Society Meetings.

Handy Decimal Equivalent Decal

Engineers, designers, draftsmen, etc., may secure a convenient time-saving decal showing decimal equivalents in 64ths, just by writing to The Meyercord Co., 5323 W. Lake St., Chicago 44, Ill. The complimentary decal is only 6 by 1¼ in. and is designed for application to slide rules, T-squares, drawing boards, desk tops and other similar drawing equipment. The figures are easy to read, printed in sharp black and red type on a white background. The company states they have enough on hand to fill any normal demand.

Welding Ideas Film

The release of a full-color strip film with sound accompaniment, entitled "Better, Faster, Cheaper with Welding," has been announced by Eutectic Welding Alloys Corp., Flushing, N. Y.

The 19-min film, it was reported, features actual case histories of unusual savings in production, maintenance and salvage, resulting from the use of proper welding techniques.

The sound accompaniment describes the various jobs pictured and in addition, explains the advanced welding methods shown on the screen in photos and diagrams.

Additional information about film content and scheduling without cost may be obtained by writing Technical Information Service, Department "P," Eutectic Welding Alloys Corp., 172nd St. and Northern Boulevard, Flushing 58, N. Y.

National Welding Supply Meeting

The National Welding Supply Assn. held its Ninth Annual Convention at the Hotel Sheraton-Gibson in Cincinnati, Ohio, on May 11–13th. This activity was one of the most successful meetings that this rapidly expanding organization has held to date.

During the meeting the Nominating Committee made its report to President G. Milton Sims. As a result, following an open election, the following officers were announced for the coming year:

President—William A. Rice, Virginia Welding Supply Co., Charleston, W. Va.

Vice-Presidents—EASTERN ZONE: Robert G. Jackson, Jackson Welding Supply Co., Rochester, N. Y.; SOUTHEASTERN ZONE: W. P. McLendon, Keenan Welding Supplies Co., Albany, Ga.; SOUTHWESTERN ZONE: R. G. Harrison, Welders Supply Co., Little Rock, Ark.; CENTRAL ZONE: James N. Alcock, Saginaw Welding Supply Co., Saginaw, Mich.; WEST CENTRAL—Marcel L. Lampton, Lampton Welding Supply Co., Wichita, Kansas; WESTERN: J. Gordon Duff, Gordon Duff, Inc., Los Angeles, Calif.

Directors (terms expiring 1956)—A. H. Homrighaus, Jr., Welder Service Co., Toledo, Ohio; George M. Avery, Scott-Foster, Ltd., Vancouver, Canada; Nolen E. Elam, Industrial Welding Supply Co., Houston, Tex.; A. C. Axtell, Essex Welding Equipment Co., Newark, N. J. To fill unexpired term of Marcel L. Lampton, year ending 1954: H. H. Kaehn, Gopher Welding Supply Co., Rochester, Minn.

The program of the convention consisted of addresses by the organization's officers and talks on subjects of direct interest to the Association's members, such talks dealing with each one of these subjects: "Safety in the Welding Industry," "Sharpening the Tools of Wholesale Management," "Layout and Display," "Training of Salesmen," "Compensation of Salesmen," "Sales Meetings," "Use of Sales Promotion Literature" and "Stock Control Methods We Are Using." Such addresses were made by H. B. Sharer, Sales Training Specialist of the U. S. Rubber Co., and by Fred O. Kiehl, Sr., Economist of the Federal Reserve Bank of Cleveland, Ohio. A welcoming address was given on Monday by Mayor Carl W. Rich of Cincinnati. The various activity committees rendered their reports on the year's business, including the zone meetings held during the previous year at Milwaukee, Philadelphia, Kansas City, Atlanta, Houston and San Francisco. In conjunction with the convention, the regular contact booth program provided the

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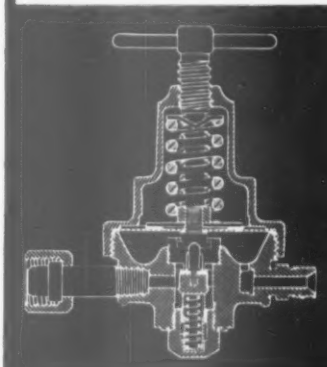

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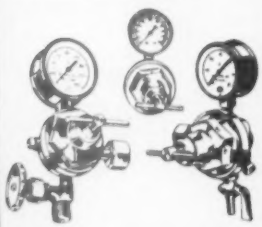

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opportunity for 72 manufacturers of welding products to meet with the dealer membership of NWSA for the purpose of discussing products, policies and the coming year's activities and business.

An excellent Ladies' Program was provided, and an informal dinner with unusual entertainment was held on Tuesday evening.

In all, the convention was a real success, and plans are now under way for six regional meetings during the coming year, plus the annual convention in the Spring of 1954.

During the course of the convention, the announcement was made that in order that even greater cooperation exist between the National Welding Supply Assn. and the AMERICAN WELDING SOCIETY, the Board of Directors of both organizations have provided reciprocal membership for each of the organizations' secretaries, each in the other organization. This will allow for an exchange of literature as well as provide a means for maintaining a closer relationship.

Passing the "Buck"

Ed Stewart of the Burdett Oxygen Co., Cleveland, Ohio, was adjudged the winner recently in a nation-wide electrode sales contest sponsored by the General Electric Co.'s Welding Department. He is shown here receiving the first-prize check from G-E sales engineer H. Hinkel (*right*), while W. H. Loveman, Burdett's presidents, looks on. Mr. Stewart's winning sale of 12,000 lb of G-E Type W-1312 electrode was the largest single electrode order received during the contest.

Chicago Stadium Uses Welding

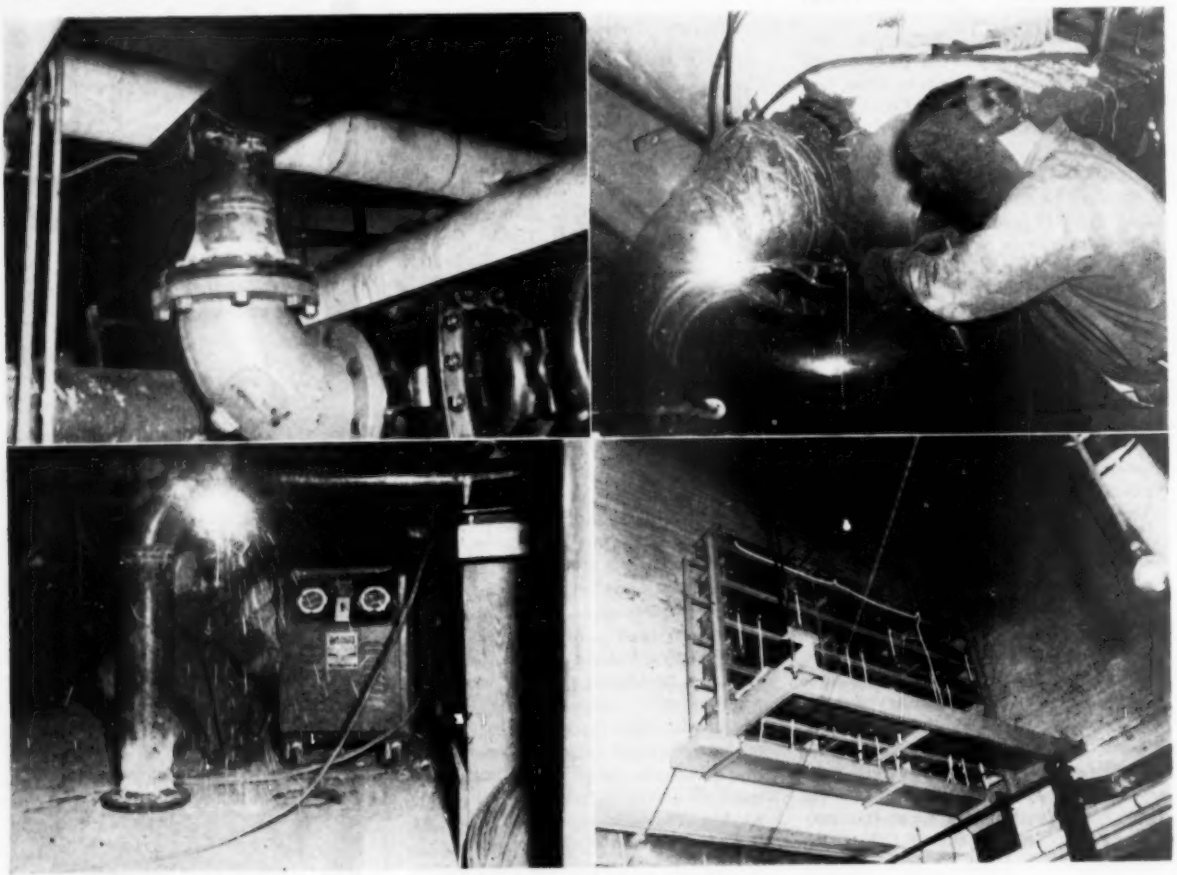
Among the many thousands of increased uses of a-c arc welding, one of the world's leading theaters of sports—The Chicago Stadium—recently completed a fabulous installation of a huge Carrier Air-Conditioning System and an icemaking machine to handle the manufacture of the extremely large ice skating rink used regularly for ice shows and sporting events.

This installation necessitated the welding of hundreds of feet of pipe line ranging in OD from 6 to 10 in. with a $^3/_8$-in. wall. In excess of 300 single pass welds were made and absolutely no breaks or leaks occurred.

In addition to the pipe-line welding which was completed using a Trindl 160-amp a-c welder, a 500-hp motor had to be placed in operation to drive the system. A mounting base had to be designed; therefore a $^1/_2$-in. thick steel framework was constructed requiring approximately 3 wk of steady welding. This construction ultimately was encased in concrete for lasting durability.

In order to handle the tremendous load of the 500-hp motor, it was also necessary to install a special switch panel for the resistors. This was made of $^1/_2$-in. channel and bar stock and was welded and assembled in place on a wall 20 ft overhead requiring a great deal of intricate positional welding.

Through the use of the 160-amp Trindl a-c machine, the stadium saved several thousands of dollars in the installation. The only material required other than this welding machine were welding rods, of which the mild steel and nickel rods of Smithway type were used. The entire job was completed in a limited time with absolutely no work stoppage and gave as-



Welding at the Chicago Stadium

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THIS TUBE-TURN Welding Return is engineered for shape, size and wall thickness to simplify piping installation. It is forged by the only process that produces a wall as uniform in thickness and true in circularity as the original seamless pipe. This assures accurate fit-up and perfect alignment . . . whether it is used as a full 180° return or cut to any odd angle.

When you specify TUBE-TURN Welding Fittings and Flanges, you are *sure* of getting the ultimate in piping simplicity, safety and permanently leakproof construction. Your nearby TUBE TURNS' Distributor is at your service!

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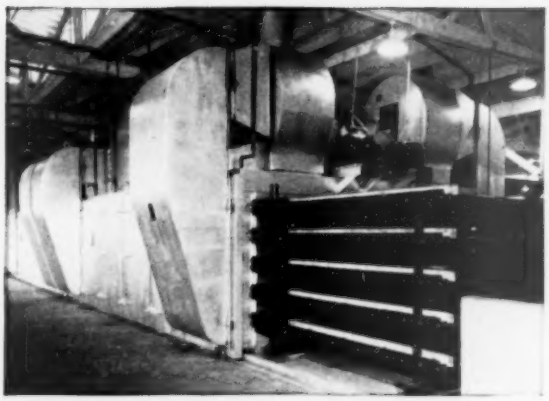
HELPS IMPROVE A DRYER DESIGN

C. B. McLaughlin, manager of TUBE TURNS' Engineering Service Division has been working with designers and piping men in the field for years. He and his men are at your service.

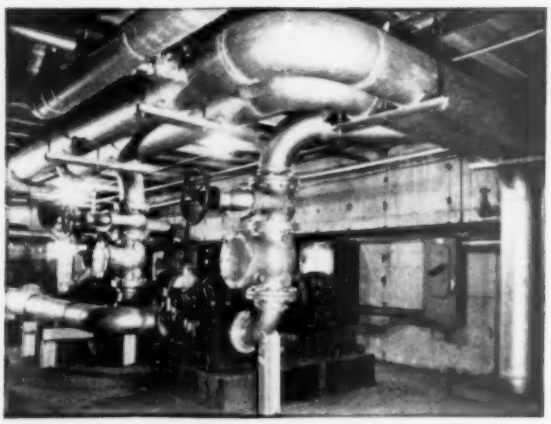
WHERE PIPING is a component of plant equipment, more and more designers are using TUBE-TURN Welding Fittings for directional changes. Results: greater design flexibility, reduced maintenance, less weight and space, improved operation. An example is the veneer dryer shown . . . a product of Coe Manufacturing Company, Painesville, Ohio. Progressive engineers of Coe, with the help of TUBE TURNS' Engineering Service Division, converted the heater from screwed connections to welded construction. Each of its banks of 1-inch pipes is joined by 180° TUBE-TURN Welding Returns. The coils carry steam at 200 psi pressure and 388°F. Joints are now permanently leakproof.

TUBE TURNS' Engineering Service is available to help in *your* piping problems.



Coe Veneer Dryer. Welded coils with TUBE-TURN Welding Returns are compact and permanently tight.

YOUR DISTRIBUTOR of TUBE-TURN Welding Fittings and Flanges can serve you promptly. He is backed up by the entire TUBE TURNS' organization.



COMPACT. Welded piping nests together . . . saves space. These condenser lines are for air conditioning system at Lazarus Department Store, Columbus, Ohio.

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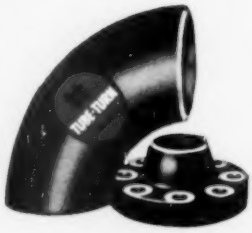

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Exacting chemical, metallurgical and, finally, spectrographic analyses are made of both ends of all coils of core wire. "Tramp" steel is immediately detected and coils in which it is found are rejected. Only coils that pass the control program are made into electrodes. Here are some of the controls:

- No more than one splice is permitted in any incoming coil.
- Samples are clipped from each end of each coil for analysis. No part of any coil can escape testing.
- When approved coils are straightened and cut, the wire is immediately sealed in boxes to prevent mixing of lots.

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SW-151	502
SW-152	505
SW-153	410
SW-154	430
SW-157	347
SW-158	317 + Cb
	318
SW-159	310
SW-160	316
SW-161	317
SW-162	308
SW-166	309
SW-168	310 + Mo
SW-169	310 + Cb
A.C.-D.C. Electrodes	
SW-357	347
SW-359	310
SW-362	308

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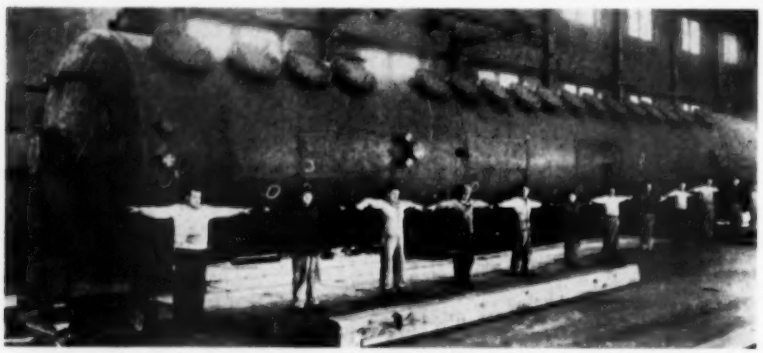
surance that an a-c welder of this variety pays for itself over again.

Lead-Clad Tower

The world's largest Ferrolum lead-clad steel tower for use in the petrochemical industry is shown in the Wilmington, Del., plant of the fabricator—Knapp Mills, Inc. The tower was built by Knapp for the Vulcan Engineering Division of the Vulcan Copper & Supply Co. of Cincinnati, Ohio, who are responsible for the basic process design.

Lead-clad metals, produced by Knapp Mills manufacturing processes, are rapidly becoming standard for use with corrosive acids because they combine the acid resistance of lead with the strength and fabricating versatility of steel.

Over-all length of this vessel is 72 ft. The outside diameter of the shell is approximately 11 ft and the skirt section is 12 ft. It weighs over 50 tons.



Dockson Corp. Celebrates 30th Anniversary

On April 15th the Dockson Corp., 3839 Wabash Ave., Detroit, Mich., and its Detroit retail organization the Sterling Dockson Co., stopped all plant operations while Harold Piggott, president of the corporation, a 30-year member of the organization, cut a mammoth birthday cake for all the employees and officers.

The Dockson Corp. was established in 1923 and Harold Piggott was the first employee. The corporation has now reached a position of national importance in the manufacture of welding equipment and head and eye safety equipment.

President Piggott attributes the successful growth of the company to the fact that it is wholly owned and operated by its employees, eight of whom have been with the company for at least half its lifetime.

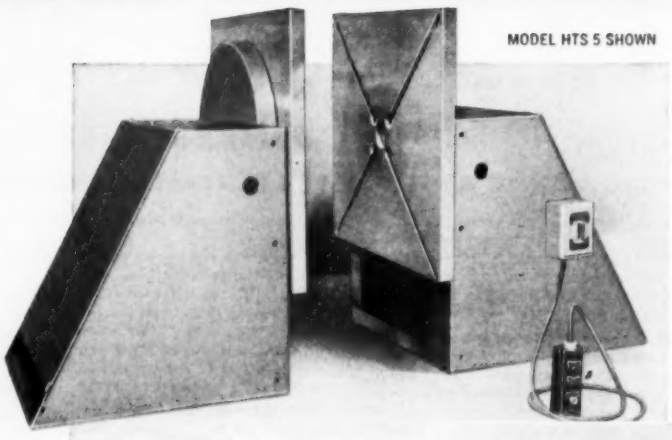
The Corporation is housed in its own modern building of 16,000 sq ft area, constructed expressly to their requirements.

The above photo shows the officers of the company (*left to right*): John F. McDevitt, Treasurer; Robert J. Nelson, Superintendent; Harold E. Piggott, President; Charles W. Piggott, Vice-President and Thomas F. Dubuque, Comptroller.

Aronson HEADSTOCKS — TAILSTOCKS

CLEAN!
SIMPLE!
RUGGED!

Roller Table Backup for Zero *Deflection* • Timken Taper Roller Bearings • Precision Steel Gears • Minimum Backlash • Magnetic Brake • Smooth, Quick Stops • All Working Parts *Enclosed Within* Chassis • Magnetic Reversing Starter *Inside Chassis* • 110 Volt Control Circuit • Positive Drive, No Belts • Mercury Grounded Spindle Headstock *and* Tailstock • All Steel, Welded Construction, No Castings • Only *Two* Grease Fittings to Service *Once a Month*



MODEL HTS 5 SHOWN

MODEL HTS 5 — Capacity 5,000 Lbs.
MODEL HTS 12 — Capacity 12,000 Lbs.
MODEL HTS 32 — Capacity 32,000 Lbs.

Rear view of HS2 Head Stock, cover removed to show clean design and simplicity of drive mechanism.

Aronson MACHINE COMPANY
ARCADE, NEW YORK

PRES COTELL, shop foreman, welds ballast equalizer of a heavy duty crane. Owner Eddie O'Rourke on the right.

"ANACONDA Welding Rods help me live up to my slogan"

—says Eddie O'Rourke, owner Industrial Welding Company, Boston

"My slogan is, 'If It's Metal We Weld It'," continues Mr. O'Rourke. "My business depends on whether or not I live up to it. A good slice of our repair work calls for us to join cast and malleable iron and build up worn surfaces on castings. For this we always use ANACONDA-997 (Low-Fuming) Bronze Welding Rods. Bronze won't pull apart. From experience, we know ANACONDA-997 Rods 'tin' readily, flow freely at low temperatures, have good tensile strength. Work needs less preheating and finished welds need less machining. ANACONDA-997 Bronze Welding Rods are economical, too. They flow better, give us more welds per rod."

Anaconda Welding Rods are available from distributors throughout the United States and Canada. Industrial Welding Co. buys its rods from Whitehead Metal Products Co. in Cambridge, whose salesman is a practical welder and contributes helpful welding suggestions. Consult your Anaconda Distributor for practical advice on welding problems. For latest tips on welding techniques, write for FREE booklet B-13 to *The American Brass Co., Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.*

53158

FOUR TRUCKS, mounted with welding equipment, speed Mr. O'Rourke and his crews to emergency jobs.

braze or weld with confidence

ANACONDA®

welding rods

NEW LITERATURE

Welding Rods

A new folder just published by All-State Welding Alloys Co., Inc., White Plains, N. Y., tells everything a professional welder, a hobbyist or an experimenter needs to know in order to properly apply any of 11 alloys, including silver solder, and their companion fluxes, and a galvanizing powder for gas welding, brazing, soldering and tinning all the commercial metals.

Copies of the new folder are available by request to the company or at any All-State Distributor's place throughout the free world.

Titanium

Titanium promises to become one of our most important structural materials. In a new technical booklet, *Properties of Titanium and Titanium Alloys*, Mallory-Sharon Titanium Corp., Niles, Ohio, provides current information on different production methods, general properties of various alloys, standard production classifications and testing procedures, and specific qualities of the five types of titanium and its alloys supplied by the company.

Mallory-Sharon will be happy to supply free copies to our readers.

D-C Welder

Miller Electric Manufacturing Co., Appleton, Wis., has new literature telling the features of Miller SR-600 selenium rectifier type, d-c welders with welding range 125 to 750 amp, and said to be the most compact 600-amp, d-c welder ever designed.

J. M. Ragle New Products

For many years the producer of the well-known Commando line of fluxes and tip cleaners for the welding industry, the J. M. Ragle Industries, are now handling the Marvel hose and cable measuring and cutting machine and wind-up reel. The new item measures true and cuts fast. It is a time saver whenever electric wire is dispensed in quantity. Parts may be purchased separately or in combination ready for mounting to meet requirements. It is approved by the Bureau of Standards. The new Marvel handles up to the largest twin welding hose and welding cable. The wind-up reel has a capacity of more than 250 ft of the largest welding cable. Cutting is neat and easy.

A new 16-page pamphlet listing the complete line of welding supplies is available by writing J. M. Ragle Industries, 4029 Indiana Ave., Kansas City 4, Mo.

Industrial Castings

Mechanite castings for industry are described in a new 8-page folder published by the American Brake Shoe Co. This division produces five engineering grades of Mechanite and several other heat- and corrosion-resistant grades. The booklet describes characteristics of the material, lists properties and carries engineering information on hardenability, section strength and comparative properties of other cast metals. Typical applications are pictured and a table of standard bar stock sizes is included. The folder may be obtained from American Brake Shoe Co., 230 Park Ave., New York 17, N. Y.

Design of Machine Elements

This book by M. F. Spotts, Professor of Mechanical Engineering, Technological Institute, Northwestern University, is published by Prentice-Hall, Inc., Publishers, 70 Fifth Ave., New York 11, N. Y., contains 504 pages and sells for $9.65. It is the outgrowth of over 20 years' experience in industry and in the classroom. The author has taught the contents many times to third- and fourth-year college students. When used as a two-semester text, there is ample material from which a teacher may select those portions best fitted to the needs of his students.

Methods based on rational analysis have been utilized throughout the book. The well-known basic theories of design are clearly presented, as well as some of the newer methods now being employed. Mathematical derivations are given in full, but have been simplified wherever possible. There is a whole chapter on welded and riveted connections.

Refractory Hard Metals

Refractory Hard Metals, by Dr. Paul Schwarzkopf, Dr. Richard Kieffer and Associates, is published by the Macmillan Co., 60 Fifth Ave., New York 11, N. Y., and sells for $10.

A modern book on this all-important aspect of powder metallurgy has long been needed, since the only existing volume is 20 years old. Also, in view of the recent developments requiring materials with substantial increases in strength and service temperatures, engineering interest is increasingly focused on the high melting carbides, borides, nitrides and silicides. In the high-temperature field, especially, much research is already being devoted to these materials because their basically different structure permits uses that cannot be achieved by mere modification or improvement of currently used alloys.

For all such research this book will be invaluable. It presents full and up-to-date information on the structure, preparation and properties of the carbides, borides, nitrides and silicides. More than that, it presents a critical evaluation, by the country's leading authorities, of these basic constituents of the hard metals, and a comparison of the performance of cemented (metal-bonded) products in the field of turbine bucket and other high-temperature applications as well as a complete discussion of refractory hard metals. It will be an important aid to metallurgists, inorganic chemists and others working on the development of materials for new engineering uses.

Spot Welding Bulletin

Sciaky Bros., Inc., 4915 W. 67th St., Chicago, Ill., Bulletin No. 306-1 covering the Sciaky SPT 2 series, air-operated, press-type, three-phase, electric-resistance spot welder has just been issued.

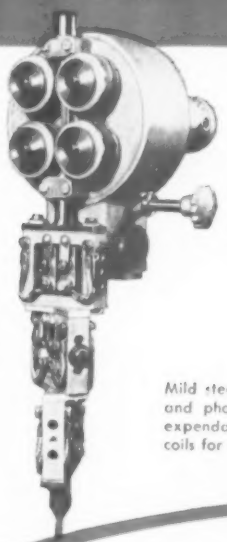
The Sciaky SPT 2 will make high-quality welds on large production runs on two thicknesses of clean mild steel in minimum gages of 0.020 in. and maximum gages of 0.102 in.—stainless steel in minimum gages of 0.020 in. and maximum gages of 0.062 in.—and in aluminum in minimum gages of 0.025 in. and maximum gages of 0.072 in.

Resistance Welding Bulletin

Sciaky Bros., Inc., 4915 W. 67th St., Chicago, Ill., Bulletin No. 305-1 covering the Sciaky EPT 2 series, air-operated, press-type, three-phase, electric-resistance projection welder is now available.

The Sciaky EPT 2 machine is one of a series of three-phase projection welders available in 50, 75 and 100 kva at 50% duty cycle. The Sciaky EPT 2 can be supplied in 12-, 18- and 24-in. throat depths and maximum electrode force of 4000 lb.

Every Welding Need

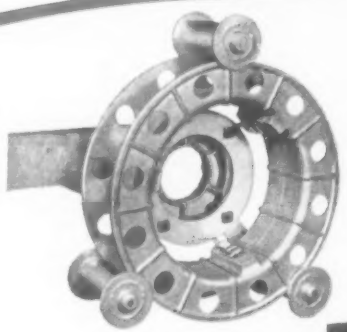


The Reid-Avery type 4R automatic head and control originally designed for Raco composite type A, may be used with equal success for lightly coated open arc or for submerged arc welding.

Raco composite type A heavy coated automatic (open arc) electrodes, a "Reid-Avery" first, can be furnished in all mild steel, low alloy high tensile, low hydrogen, hard surfacing and stainless steel grades.

Mild steel, alloy steel, stainless steel, aluminum and phosphor bronze wire are available on expendable wooden spools or in layer wound coils for gas shielded arc welding.

The Raco "free wheeling" reels are especially designed for high speed automatic machines. The ball bearing trunnions enclose the coil so there is no over-run or loose strands and larger coils can be used. Changing coils is a matter of only a few seconds and no tools are required. Available in 12, 14, 25 and 36 inch sizes, for any weight from 50 to 200 lbs.



The Raco coils of wire for submerged arc welding have long been known for their uniform high quality and convenient, easy to handle package. Special attention is paid to the accurate weight, lay and temper of the wire so that the wire will accurately follow a seam. Available in mild steel, alloy steel and stainless steel.

Since 1919 Reid-Avery Company has specialized in the manufacture of all types of welding electrodes and wire. The large modern plant in Baltimore is equipped for wire drawing, annealing, pickling, coating, cutting, winding and packaging. Every phase of welding electrode and wire production is completely controlled from start to finish. You can be assured of uniform high quality and the best possible deliveries.

We also manufacture a complete line of manual electrodes in the following grades:
Raco Mild Steel, Raco Low Alloy High Tensile, Racocast for nonmachinable welds on cast iron, Raco Feral for welding aluminized sheets, Raco Low Hydrogen, Raco Hard Surfacing, Racolloy Stainless, Racolloy Nickel and Nickel 60 for machinable welds on cast iron.

The REID-AVERY COMPANY
INCORPORATED
DUNDALK • BALTIMORE 22 • MARYLAND
SINCE 1919 PRODUCERS OF ARC WELDING ELECTRODES AND WELDING RODS

Ductalloy Castings Booklet

American Brake Shoe Co. has issued a new, 12-page booklet on industrial castings of Ductalloy (Brake Shoe's trade name for ductile iron). Properties, characteristics and applications are described for three standard grades of Ductalloy produced by two divisions of the company. Pictured are typical castings for use in aviation, chemical, Diesel and general industrial fields. The booklet can be obtained by writing to Department A, 230 Park Ave., New York 17, N. Y.

Booklet on Electrodes

Air Reduction recently announced the availability of an up-to-date, 50-page pocket guide to Airco electrodes.

Over 30 different electrodes—stainless, mild and high-tensile steels, cast iron, nonferrous, low hydrogen and hard facing are described as to chemical analysis, procedure for welding and application.

Other sections in the booklet include "Picking the Right Electrode," mechanical properties and testing of electrodes, and AWS-ASTM specifications.

A copy of this illustrated guide (Form ADC 650) can be obtained by writing Air Reduction Sales Co., 60 E. 42nd St., New York 17, N. Y.

Welding, Brazing, Soldering of Aluminum

Any engineer familar with the welding of the older metals will find all he needs to know about welding, brazing and soldering aluminum in the new 186-page process manual, *Welding Aluminum*, just published by Reynolds Metals Co., Louisville, Ky.

This is a new and greatly enlarged edition of the manual by the same title originally published by Reynolds in 1946. The new edition contains material on 34 processes suitable for welding, brazing and soldering aluminum and its alloys. These processes are shown in a large chart revealing their relation to one another and indicating those processes most widely used.

A second chart breaks down the wrought aluminum alloys and shows the various joining methods suitable for the various alloys. A third chart covers the aluminum casting alloys in a similar manner.

Detailed weldability ratings for the wrought alloys and casting alloys are presented in tables rating them for gas-, arc- and resistance-welding processes as well as for brazing and soldering.

The factors that give the aluminum alloys their particular welding characteristics are explained, and definitions of the 34 welding, brazing and soldering processes are included.

A section explains the alloy and temper designations used for aluminum. In addition to the older methods such as gas welding, metal-arc, carbon-arc and atomic-hydrogen arc welding, separate chapters are devoted to the newly developed processes such as inert-gas-shielded metal arc, and the multiarc.

Flow welding, stud welding and induction welding are other comparatively new processes described in the manual.

In the resistance-welding section, important advances in flash and percussion welding are presented. These permit making welds with practically no upset metal "flash." Detailed procedure is given for producing flash welds that actually measure less than 0.001 in. (one thousandth of an inch) across the weld. Such joints can be made in high-alloy heat-treated aluminum without appreciably lowering the strength through the weld zone. Also they greatly reduce cost since there is no upset metal "flash" to be ground off in finishing the weld.

Another new development that has created much interest recently is "cold" welding—one of the two methods of "pressure" welding discussed in the Reynolds manual. In cold pressure welding, the two work surfaces to be joined are brought together under pressure, sealing these surfaces off from the atmosphere. Further pressure is then applied by dies so shaped as to cause the metal at the contact surfaces to move sidewise or "grow" sidewise. This action exposes clean fresh metal from below the contact surface of each part. Continued application of force causes these new metal surfaces to join each other, producing a true weld with a continuous grain structure.

The manual includes illustrations of lap joints in sheet as well as butt and lap welds in wire—all made by the process just described.

In the chapters on brazing aluminum, two new processes—induction brazing and resistance brazing—are described, in addition to the more widely known methods of torch, furnace and salt bath (dip) brazing. Joint designs, jigs and fixtures, recommended materials and procedure are presented. The various types of brazed joints include a special design for joining tubing, worked out by Reynolds engineers for the refrigeration industry to prevent brazing flux from entering the refrigeration system.

The soldering chapter explains the factors that make aluminum soldering different from conventional soldering. It includes complete procedure recommendations as well as listing solders and fluxes that have proved satisfactory.

The section on weld inspection contains complete information on how to qualify welding operators to produce work meeting the requirements of the U. S. Army Air Force, U. S. Naval Aircraft Factory, U. S. Navy and others.

AT THE FRONTIERS OF PROGRESS YOU'LL FIND

AN AIR REDUCTION PRODUCT

For Welding and Cutting . . .

NATIONAL CARBIDE

in the red drum

HIGHEST QUALITY
DUST FREE

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National Carbide Company

GENERAL OFFICES: 60 EAST 42ND STREET, NEW YORK 17, N. Y.

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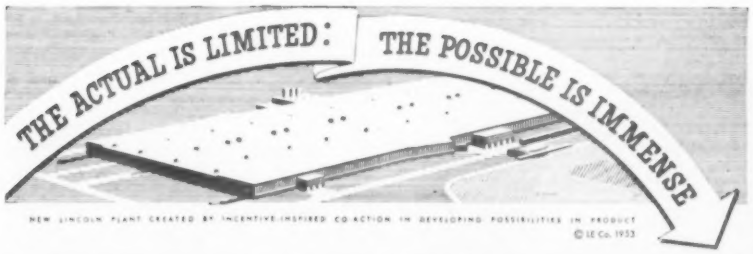
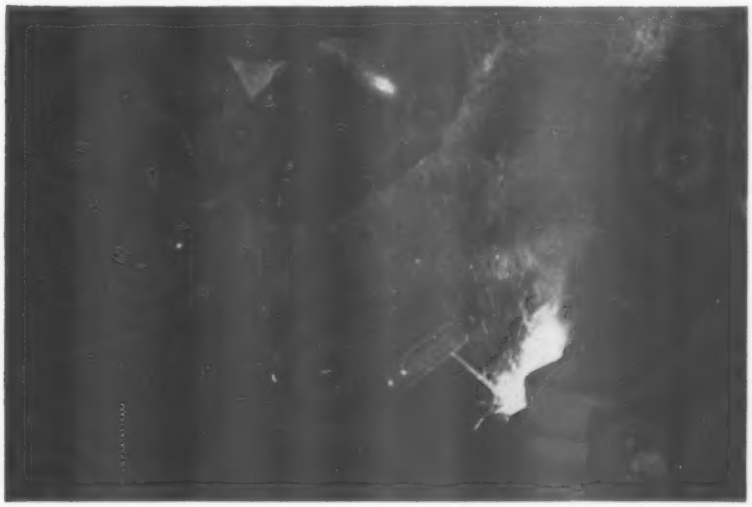


NEW LINCOLN PLANT CREATED BY INCENTIVE-INSPIRED CO-ACTION IN DEVELOPING POSSIBILITIES IN PRODUCT
©LE Co. 1953



FOR 35% MORE SPEED

...specify Lincoln "Fleetweld 72"

Performance proves "Fleetweld 72" welds 35% faster than other E-6012 electrodes . . . cuts welding costs of 3 out of 4 production jobs. And that's not all.

Welds made with "Fleetweld 72" are smoother, of higher quality. And "Fleetweld 72" has good "wetting" action with minimum arc force.

"Fleetweld 72" operates beyond the breakdown point of other rods . . . without overheating, without excessive arc spatter. Its higher melt-off rate and flatter bead give you more mileage or stretch per length of rod than possible in any E-6012 electrode today. What's more, most welds are self-cleaning.

Readily available, "Fleetweld 72" answers the demands of many production jobs normally specified for E-6013 calling for smooth appearance and easy slag cleaning. Selling for less cost per pound, "Fleetweld 72" further helps you meet the challenge for lower welding cost on a host of production operations.

START CUTTING WELDING COSTS—Latest Speeds and Procedures for production welding with Lincoln "Fleetweld 72" are in the Weldirectory 462. Available by writing on your letterhead to Dept. 1907.

THE LINCOLN ELECTRIC COMPANY
CLEVELAND 17, OHIO
THE WORLD'S LARGEST MANUFACTURER OF ARC WELDING EQUIPMENT

LINCOLN "FLEETWELD 72"

Unique E-6012 Electrode for High Speed Production Welding of Lap and Fillet Welds

Faster, Easier Operation Lincoln "Fleetweld 72" operates with peak efficiency at welding currents substantially above conventional E-6012 electrodes and without danger of breakdown. Weld deposits produced at high melt-off rates are smooth, are slightly convex . . . ideal for all types of flat position production work where duplicate welds must be made in the shortest time to cut shop costs.

Proper Root Penetration The unidirectional arc characteristics of Lincoln "Fleetweld 72" assure correct root penetration of fillet welds . . . with minimum cutting away of the top edge of lap welds, yet without sacrifice in speed.

More Mileage Fleetweld's near-flat bead means top weld strength without piling up weld metal as experienced with other electrodes. This means more mileage per length of rod to cut electrode costs.

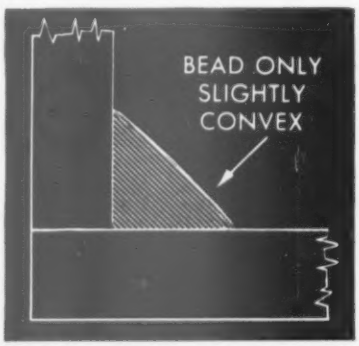


Fig. 1. More Mileage *comes from "Fleetweld 72's" near-flat bead shape. There is no piling up of weld metal.*

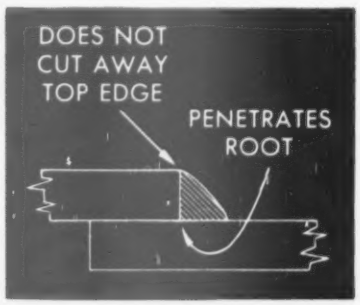
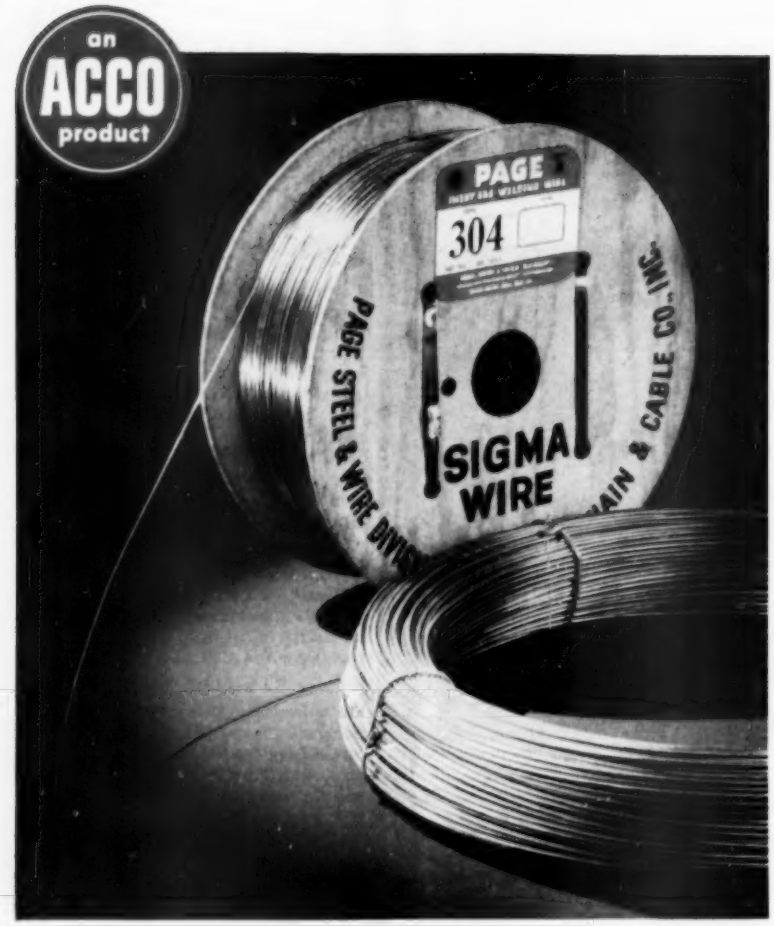


Fig. 2. Quality at Top Speed. *Proper penetration at root is done without cutting away top edge.*



Why You Should Use...
PAGE Automatic Welding Wire

• PAGE Automatic Welding Wire is made to rigid specifications which provide consistent characteristics for smooth flow of metal during continuous or intermittent welding. There are many analyses for a wide variety of uses.

for INERT GAS Welding

PAGE Stainless Steel Wire is precision thread-wound on 25-lb. non-returnable convenient reels which fit popular arc welding machines. Six Page-Allegheny grades; wire diameters: .035", .045", .0625".

for SUBMERGED ARC Welding

PAGE stainless, low alloy, and carbon steel wire in layer-wound coils, in 22" or 24" mill coils, or on 200-lb. returnable steel reels. Wire diameters from 1/32" to 5/16"; copper coated if desired.

ACCO

Write to our Monessen, Pennsylvania office for Bulletin DH-402

PAGE STEEL AND WIRE DIVISION
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PAGE Welding Electrodes AND Rods

Aluminum-coated steel ("aluminized" steel) combines the advantages of both metals and is finding wide use in high-temperature applications. A section in the new manual presents recommended materials and procedures for welding, brazing and soldering this unique product.

The book contains 35 tables, most of which are devoted to detailing machine settings and exact welding procedure for the various processes. There is a Table of Contents, an Index of Tables, and a 15-page Itemized Cross Index with references to text, illustrations and tables.

The current revision of this book was prepared by Charles Bruno, Reynolds Chief Welding Engineer. He also contributed the new material found in this issue. The book was edited and produced by G. W. Birdsall.

This 186-page manual is ring bound to lie flat when open; is convenient 6- x 9-in. pocket size. It contains more than 125 charts and illustrations. It will be sent without charge to any engineer, designer, technical man or company executive requesting it on company letterhead. To others, the price is $1.00 per copy. Write Desk PR, Reynolds Metals Co., 2500 S. Third St., Louisville 1, Ky.

Low-Hydrogen Electrodes

Alloy Rods Co., York, Pa., leading manufacturer of alloy arc-welding electrodes, has published a new 8-page technical bulletin by Richard K. Lee, Vice-President in Charge of Research, and J. O. Cavanagh, Technical Director, entitled *The Facts About Low Hydrogen Electrodes.*

This bulletin deals with recent technical developments in the low-hydrogen electrode field, with chapters devoted to history of this type of electrode, effects of hydrogen, effects of the basic slag, control of hydrogen, welding procedures and applications.

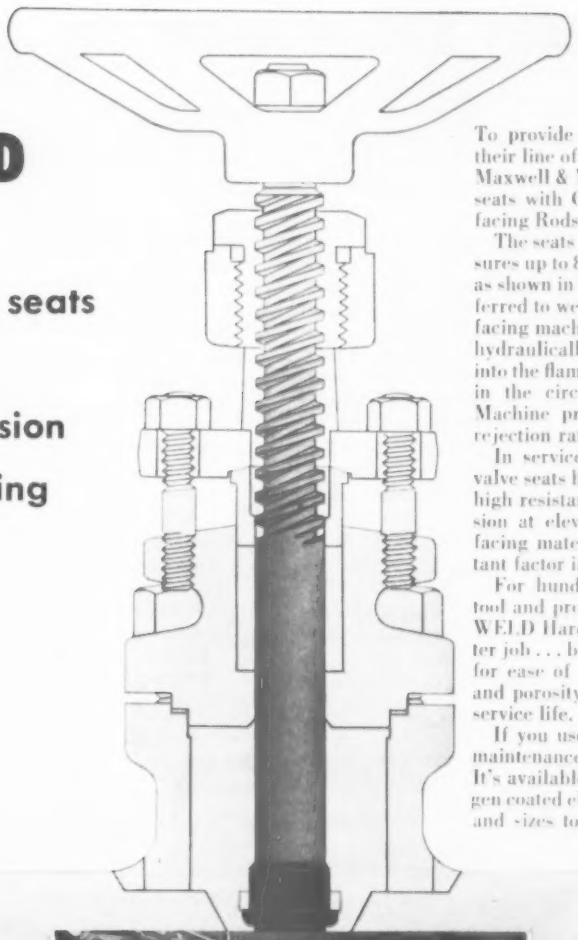
Copies of the bulletin may be secured by writing the Alloy Rods Co., York, Pa., and requesting Bulletin AR53-18.

Nickel Steel Tubing

New 9% Nickel Steel Tubing—Properties and Processing—10 pages documented with charts, tables and photographs. Describes its mechanical and working characteristics, heat treating behavior and weldability. Presents data showing that it is suitable for low-temperature (−320° F) service; also for the oil industry where chloride salts, hydrogen sulfide, carbonic acid and certain organic acids are encountered; for the paper industry where sodium hydroxide and black liquors are met; and for the chemical industry because of its greater resistance than ordinary carbon or low-alloy steels to corroding influences, and its toughness and high physical strength. International Nickel, New York 5, N. Y.

REXWELD

hard-faced Hancock valve seats resist erosion, corrosion, abrasion ...are non-galling



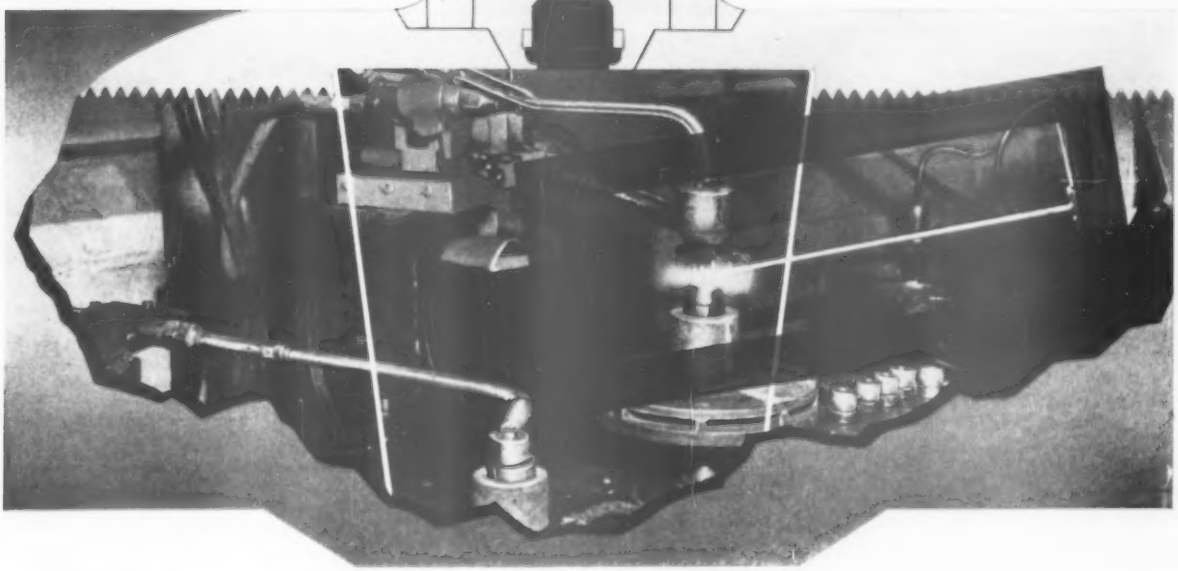
To provide long, trouble-free service life for their line of Hancock gate valves, the Manning Maxwell & Moore Company hardface the valve seats with Crucible REXWELD A Hard Surfacing Rods.

The seats for these valves, which handle pressures up to 800 psi at 750°F, are first preheated as shown in left portion of photo . . . then transferred to welding table of semi-automatic hardfacing machine. After welding head is lowered hydraulically, a rod of REXWELD A is fed into the flame and the molten metal is deposited in the circular recess in the seat surface. Machine produces 70 seats an hour, with a rejection rate of only 1%.

In service these REXWELD hard-surfaced valve seats have demonstrated an exceptionally high resistance to erosion, corrosion and abrasion at elevated temperatures, and the hardfacing material does not gall — a very important factor in good valve operation.

For hundreds of other applications where tool and product life must be increased, REXWELD Hard Surfacing Rods have done a better job . . . because they are especially designed for ease of application and to produce crack and porosity free surfaces that give maximum service life.

If you use hard surfacing in production or maintenance, be sure you order REXWELD. It's available in both bare rods and low hydrogen coated electrodes—in many different grades and sizes to meet your specific requirements.



CRUCIBLE first name in special purpose steel

53 years of Fine steelmaking

REXWELD HARD SURFACING ROD

CRUCIBLE STEEL COMPANY OF AMERICA, GENERAL SALES OFFICES, OLIVER BUILDING, PITTSBURGH, PA.

REZISTAL STAINLESS • REX HIGH SPEED • TOOL • ALLOY • MACHINERY • SPECIAL PURPOSE STEELS

PERSONNEL

Parks Joins Airco

Dr. John M. Parks became Manager of the Metallurgical Process Division of the Air Reduction Research Laboratories, Murray Hill, N. J., on May 1, 1953. He was formerly Supervisor of Welding Research at the Armour Research Foundation in Chicago.

Dr. Parks is a graduate of Purdue University and Rensselaer Polytechnic Institute. He was an Assistant Professor at Rensselaer and Editor of miscellaneous publications for the American Society for Metals. During the last decade he has actively engaged in metallurgical and welding research and development, including work on arc welding, brazing and recrystallization welding.

He is active in SOCIETY affairs, as a member of the AWS Committee on Awards, and as Program Chairman and Vice-Chairman of the Chicago Chapter, AWS. In Houston he recently presented two papers: one on "Recrystallization Welding," the other on "Brazing of Titanium."

S. L. Hoyt Becomes Consultant

As of June 1st, Dr. S. L. Hoyt retired as Technical Advisor at Battelle Memorial Institute to engage in consulting practice. He is remaining as part-time consultant for Battelle and will divide his time between the operations at Columbus and those in Europe. The rest of the time he will be occupied as a metallurgical consultant in the fields of research and development, and metals technology, with headquarters at 32 Blenheim Road, Columbus 14, Ohio.

After teaching six years at the University of Minnesota, Dr. Hoyt resigned to become research metallurgist with the General Electric Co. for 12 years, where he developed Carboloy and introduced it into practice. He was with the A. O. Smith Corp. for 10 years and since 1939 has been with Battelle, where he has been active in metallurgical research and development and in the application of metals technology to welding practice and to problems of procurement, fabrication and end uses.

Dr. Hoyt is known to the profession through his lectures, technical papers and books, particularly as the author of *Metal Data* now in its second edition. He is also active in organizations with which he is associated, such as AWS, ASM, ASTM, AIME, etc., and is a member of the Welding Research Council and the Committee on Ship Steel. He is also metallurgical representative on the Scientific Advisory Council of Picatinny Arsenal.

Sangdahl Promoted

George S. Sangdahl was elected a Vice-President of the Chicago Bridge & Iron Co. on Apr. 13, 1953. He has been associated with the company since Jan. 15, 1915.

Mr. Sangdahl was graduated with a B.S. degree in Engineering from the University of Illinois in 1913. He started working in the Sales Department of the Chicago Bridge & Iron Co. doing design and estimating work, was Manager of the Montreal, Que., Sales office of the company's Canadian affiliate, Horton Steel Works Ltd., for five years, and has been Manager of the Company's Cleveland Sales office since 1925.

On May 4th Mr. Sangdahl became Manager of a new sales office which the Chicago Bridge & Iron Co. opened in Pittsburgh, Pa. It is located in the Alcoa Building.

Mr. Sangdahl is a member of the SOCIETY.

OBITUARY

G. Wm. Plinke

G. Wm. Plinke, Director of Research and Welding, Henry Vogt Machine Co. Louisville, Ky., passed away suddenly on Apr. 11, 1953, in his 54th year, having faithfully served continuously in the employ of that company for a period of 28½ years.

Born in Louisville, Ky., Mr. Plinke graduated from Purdue University in 1920 and over the period of years has lent his energy, enthusiasm and ability to many worth-while activities. He served his country in World War I as a Lieutenant, Heavy Artillery, U. S. Army, and later in civilian life served as President, Falls City, Purdue Alumni Assn., and Chairman, Louisville Section, AMERICAN WELDING SOCIETY. He made valuable contributions to the progress of welding, both gas and electric-fusion, having published numerous papers and serving as author and co-author of chapters for early editions of the WELDING HANDBOOK of the AMERICAN WELDING SOCIETY and The International Acetylene Assocn.

Mr. Plinke is survived by his wife. He will be greatly missed by his associates and host of friends. His genial smile, sincere friendliness, sterling character, stimulating personality and Christian principles will long be remembered and inspire continued activity in his field.

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WIRE FOR WELDING

- STAINLESS STEELS
- ALLOY STEELS
- ALUMINUM
- BRONZES
- SPECIAL ALLOYS

WELDSPOOL

the ONLY chemically processed precision spooled electrode wire designed and suitable for ALL TYPES—ALL MAKES inert gas welding equipment

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the covered electrodes with BUILT-IN-QUALITY

ALSO ASK FOR
"WELDWIRE" Gas Welding Rods
"WELDCOIL" Submerged Arc Wire
"WELDSPRAY" Metallizing Wire

AND FOR CUTTING or GOUGING
"WELDBEST" Arc Oxygen Cutting Rods
"WELDBEST" Cutting Rod Holder
"WELDBEST" Underwater Cutting Electrodes

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ELECTRODES, WIRES, FLUXES

For Welding Monel · Nickel · Inconel

NICKEL

Oxy-Acetylene	"41" Nickel Gas Welding Wire	For welding of Nickel—no flux required
Submerged Melt	"51" Nickel Wire	For welding Nickel
Inert Gas Metal-Arc	"61" Nickel Wire	For welding Nickel
Metal-Arc	"131" Nickel Welding Electrode D.C.	For welding Nickel or Low Carbon Nickel
	"141" Nickel Welding Electrode D.C.	For welding Nickel to steel; overlaying Nickel on steel

LOW CARBON NICKEL

Metal-Arc	"131" Nickel Welding Electrode D.C.	For welding Low Carbon Nickel

MONEL®

Oxy-Acetylene	"40" Monel Gas Welding Wire	For welding Monel using INCO "3" Gas Welding Flux
	"43" Monel Gas Welding Wire	For welding heavy sections of "326" Monel for acid pickling service—no flux required
Submerged Melt	"50" Monel Wire	For welding Monel
Inert Gas Metal-Arc	"60" Monel Wire	For welding Monel
Metal-Arc	"130" Monel Welding Electrode D.C.	For welding Monel
	"140" Monel Welding Electrode D.C.	For welding Monel to steel and overlaying Monel on steel

"K"® MONEL

Oxy-Acetylene	"44" "K" Monel Gas Welding Wire	For welding "K" Monel, using 2 parts INCO "2" or INCO "3" Gas Welding Flux and 1 part Lithium Fluoride
Inert Gas Metal-Arc	"64" "K" Monel Wire	For welding "K" Monel
Metal-Arc	"134" "K" Monel Welding Electrode D.C.	For welding "K" Monel

70/30 COPPER-NICKEL

Metal-Arc	"137" 70/30 Copper-Nickel Welding Electrode D.C.	For welding 70/30 Copper-Nickel

INCONEL® · INCOLOY®

Oxy-Acetylene	"42" Inconel Gas Welding Wire	For welding Inconel and Incoloy using INCO "2" Gas Welding Flux
Inert Gas Metal-Arc	"62" Inconel Wire	For welding Inconel and Incoloy
Metal-Arc	"132" Inconel Welding Electrode D.C.*	For welding Inconel and Incoloy; and Inconel and Incoloy to steel
	"142" 80/20 Nickel-Chromium Welding Electrode A.C.-D.C.	For welding Inconel and Incoloy to steel and overlaying on steel

INCONEL "X"® · INCONEL "W"®

Inert Gas Metal-Arc	"69" Inconel "X" Wire	For welding Inconel "X" and Inconel "W"
Metal-Arc	"139" Inconel "X" Welding Electrode D.C.	For welding Inconel "X" and Inconel "W"

CLAD STEELS

Metal-Arc	Nickel and Low Carbon Nickel-Clad	"141" Nickel Welding Electrode D.C.	For welding Nickel and Low Carbon Nickel side only
	Monel Clad	"140" Monel Welding Electrode D.C.	For welding Monel side only
	Inconel Clad	"142" 80/20 Nickel-Chromium Welding Electrode A.C.-D.C.	For welding Inconel side only

CAST IRON · DUCTILE IRON · NI-RESIST®

Metal-Arc	NI-ROD "55"® Electrode A.C.-D.C.	For welding Cast Iron, Ductile Iron, Ni-Resist, and other alloy irons to themselves and to other metals

FLUXES

INCO "1" Gas Welding and Brazing Flux—For welding and brazing copper-nickel and other copper alloys

INCO "2" Gas Welding Flux—For welding Inconel, all stainless steels, rustless irons and other chromium-containing alloys

INCO "3" Gas Welding Flux—For welding Monel and other Nickel-copper alloys

*"132" electrodes larger than 3/32" diameter can also be used with A.C. transformers.

For further information, write for Technical Bulletin T-2 "Fusion Welding of Nickel and High Nickel Alloys."

Your Distributor of Inco Welding Materials can supply you with a copy as well as the latest information on deliveries.

The International Nickel Company, Inc.,
67 Wall Street, New York 5, N. Y.

INCO

NEW PRODUCTS

Mild Steel Electrode

Air Reduction just announced the availability of a new, improved E-6010 electrode, the Airco 78E, for welding mild steel in all positions.

This new electrode offers deep penetration without undercutting, a minimum of spatter and uniform weld deposits without fingernailing. The deposit solidifies quickly which especially adapts this electrode for welding in the vertical and overhead positions.

The 78E is recommended for the fabrication of mild steel involving plate and rolled sections or castings, fired and unfired pressure vessels, structural frames, pipe lines and all classes of marine work where high ductility and tensile strength are essential.

For complete details on this electrode and Airco's complete line, request a copy of *Pocket Guide to Electrodes*, by writing Air Reduction Sales Co., 60 E. 42nd St., New York 17, N. Y.

Welding Helmet

A new arc-welding helmet of the lift-front type is announced by Jackson Products, Warren, Mich.

The front of the lens holder, made of high-impact, molded plastic, holds protective filter lens and clear cover glass and swings up to permit inspection of work without raising the entire helmet, while another clear glass stays in place to protect the eyes.

Helmet shell is of one-piece, thermosetting plastic reinforced with glass fiber. It resists high heat, high voltage, moisture and spatter, is strong and easy to clean.

Headgear has wide, flexible straps ma le of smooth, easy-to-clean plastic. Adjustable and calibrated to hat sizes, it is quickly made to fit before putting it on, and has replaceable cork-padded sweatband.

Helmet swings up on friction pivots, adjustable without taking the helmet off. Helmet can be made to float down without jolting stops, or to stay in any desired position.

Radio Interference

A low-cost shielded enclosure specifically designed for avoiding radio spectrum interference has just been announced by the Ace Engineering & Machine Co. Made up of standard size panels framed in white pine with galvanized steel screening stretched across the outer surface, it may be easily erected, taken down or enlarged. Virtually any kind of electrical or mechanical power, water, gas or other service can be brought into the enclosure. Tested by an independent laboratory, its attenuation is at least 40 DB, even under the most adverse circumstances. The most inexpensive commercially produced enclosure, it permits compliance with the FCC requirements at lowest cost and with least time wasted.

It is imperative that shops and factories employing induction heating, dielectric sealing and electric welding equipment be certain that their installations do not violate Part 18 of FCC Rules and Regulations. As a free public service, an official copy of Part 18, and a bulletin describing the low-cost solution of the interference problem, will be sent upon request by the Ace Engineering and Machine Co., 3644 N. Lawrence St., Philadelphia 40, Pa.

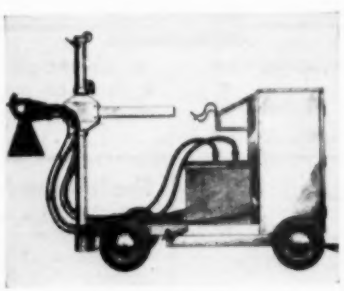
New Mobile X-Ray Unit

An improved 250-kv, mobile X-ray unit (Model 413) for radiographing unwieldy objects that require positive X-ray inspection is available from the Westinghouse Electric Corp.

Improvements in the new model are principally in flexibility and ease of handling. The operator has been given additional protection so that he can stand inside the cab. The radius of turn has been improved so that the unit can be more easily positioned. The chassis has been strengthened and the center of gravity lowered.

Wide inspection coverage is accomplished with a long vertical column and a horizontal tube arm. The minimum distance from tube head to floor is 36 in. and the maximum 108 in. Throughout this 72-in. vertical travel, the tube head has a horizontal travel of 48 in. The vertical column can be rotated 360 deg.

A 250-kv constant potential transformer provides power for radiographing up to 4½ in. of steel and proportionally thicker sections of lighter density materials.



For further information, write Westinghouse Electric Corp., Section X, 2519 Wilkens Ave., Baltimore 3, Md.

Welding Press Transformer

The recent adoption of specifications for Type "A-1" welding press transformers by JIC (Joint Industrial Conference) and RWMA (Resistance Welder Manufacturers Assn.) has resulted in the development of a new product designated as Kirkhof Type R, 50 kva, welding transformer.

This unit, available for use on either 220- or 440-v, 60-cycle service, was developed primarily through the use of grain-orientated, high-permeability, Type "C" silicon iron cores; also, improvements in the water cooling system and other design features have contributed to its efficiency. Current regulation is obtained by a built-in four-step regulator giving a secondary voltage range of 3.2 to 5 v.

This small and compact package type transformer, weighing only 137 lb, has been an important factor in the design and manufacture of special high-production multispot resistance welding equipment.

Resistance-Welding Electrode Holder

Sciaky Bros., Inc., 4915 W. 67th St., Chicago, Ill., has issued Bulletin No. 310-10 covering the Sciaky Micro-Metric Upper Electrode Holder which provides an extremely accurate and simple method for precise alignment of electrode tips to

AMSCO V-MANG

The new moly-manganese electrode that's better than nickel-manganese rods for build-up and repair

- TOUGHER DEPOSIT
- BETTER WELDABILITY
- HIGHER YIELD STRENGTH
- LESS CRACKING

Comparison of yield and tensile strength

For full engineering and metallurgical information on Amsco V-Mang, write for technical data sheet to Amsco, Chicago Heights, Illinois.

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THE RIGHT WAY TO SAY HARDFACING

AMERICAN Brake Shoe COMPANY

AMERICAN MANGANESE STEEL DIVISION
399 EAST 14th STREET • CHICAGO HEIGHTS, ILL.

Other Plants: New Castle, Del., Denver, Oakland, Cal., Los Angeles, St. Louis. In Canada: Joliette Steel Division, Joliette, Que.
Amsco Welding Products distributed in Canada by Canadian Liquid Air Co., Ltd.

weld to rigid, Government and aircraft specifications.

The Sciaky Micro-Metric Upper Electrode Holder insures the proper alignment of electrode tips for consistent top quality to Commercial Standards. Precise alignment of electrodes makes high production welding possible on piece parts with minimum overlap or where small edge distance is necessary to design requirements.

The precise alignment of electrodes in the Sciaky Micro-Metric Upper Electrode Holder can result in a substantial saving in tip replacement. Electrode tips properly aligned last longer with less downtime in production for tip dressing.

New E-6010 Electrode

A new, easy operating, mild steel E-6010 electrode, "Fleetweld 51," has been put on the market by The Lincoln Electric Co. of Cleveland, Ohio. It is a shielded arc electrode designed for all position welding with direct current.

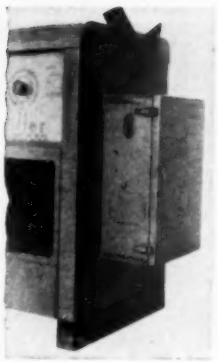
The new "Fleetweld 51" is well suited for welding of all types of joints in the overhead or vertical position. It is especially well suited for "vertical up" welding. It produces flat-faced fillets when welded in a vertical position and reduces sagging or excessive convexity on welds made in any position.

"Fleetweld 51" may also be used with excellent results for welding galvanized, dirty or rusty plate; welding pipe in all positions with "vertical up" techniques; applications requiring maximum penetration and applications requiring physical properties of an E-6010 type electrode. "Fleetweld 51" is a deep penetrating electrode. Arc characteristics secure excellent root penetration, and the weld is fast freezing with an exceptionally small volume of slag. The deposits have excellent physical properties.

This new electrode is available in 14-in. lengths and in the following diameter sizes: $^1/_8$, $^5/_{32}$, and $^3/_{16}$ in.

Welding Control Unit

To facilitate operation of any number of Miller Selenium Rectifier Type D-C arc welders in parallel is the new control unit manufactured by Miller Electric Manufacturing Co., Appleton, Wis. Designated as Model SRSM Series, this unit, housed in a neat metal cabinet, contains a primary contactor of sufficient rating to adequately handle 3-phase primary current of a $^1/_2$-kva control transformer that operates the contactor and cooling fan motor, and supplies energy to the current control circuit. Suitable interlock switch furnishes finger-tip control over the various welders in the paralleled hook-up. The metal cabinet is attached readily to the side of any Miller SR Welder and does not interfere with the normal operation of the machine itself. One SRSM Control Unit is required for each welder to be operated in a parallel setup, which permits any number of the individual welders to cut into the circuit at the flick of a switch.



Welding Control Unit

Fluxing Compound

A new fluxing compound for use in soldering aluminum has just been announced by the Essex Wire Corp. Differing entirely from conventional fluxes, this new product, known as S-X Aluma-Flux, now makes possible the noncorrosive soldering of aluminum alloys (except a few containing high percentages of silicon) as well as the joining of aluminum to other metals.

CHAMPION
Welding Accessories are Everything the Name Implies
WELDING GOGGLES
ELECTRODE HOLDERS
HELMETS
WELDING GLOVES
AIR HAMMERS
DUAL TOOLS
GROUND CLAMPS
CLAMPS
LEATHER CLOTHING
WELDING CABLE
There's a CHAMPION item for practically every welding need. For longer wear and better function choose the line preferred by veteran welders.
You can't beat a CHAMPION!
Send for a copy of our complete catalog on all types of Accessories — ask for No. 50-A.
THE CHAMPION RIVET CO.
CLEVELAND 5, OHIO and East Chicago, Indiana

NEW! SIMPLIFIED! SMALLER!

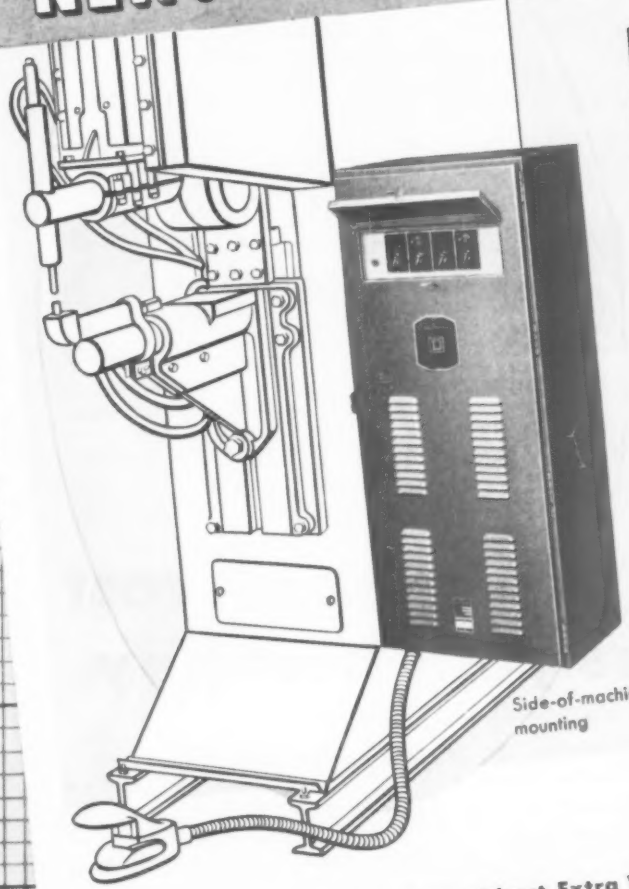
ELECTRONIC NON-SYNCHRONOUS WELDER CONTROL

Here is design simplification that affords significant advantages—easy installation, less maintenance, smaller size, mounting versatility.

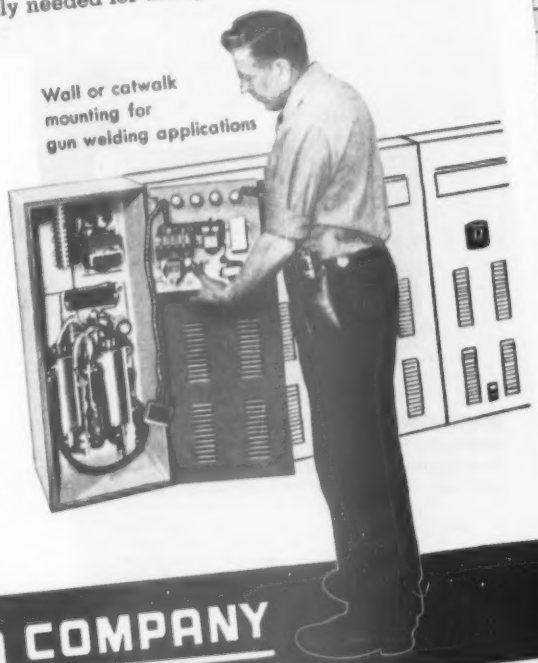
Drastically simplified NEMA 3B weld and sequence timing circuit requires only 4 tubes plus valve relay and firing relay. Extreme consistency and timing accuracy are maintained. All tube circuits are "fail-safe." Firing of power tubes is synchronized to minimize transients and ease stress on welding transformer.

Interchangeable NEMA 3B and 5B timer panels are quickly detached from door. Plug-connectors to power pack in cabinet permit easy replacement.

Much smaller in size, this new controller (15" x 15" x 37") requires little more space than formerly needed for the ignitron contactor alone.



Side-of-machine mounting



Wall or catwalk mounting for gun welding applications

Wall or Machine Mounting without Extra Work

• Enclosure design permits wall or side-of-machine mounting with the same controller and without the additional trouble of relocating adjuster dial assembly. Installation is made easier by generous wiring space below contactor, and vertical wiring channel extending the full height of the cabinet. All components are arranged for maximum accessibility.

Write for Bulletin 8992 *on Electronic Non-Synchronous Welder Control and its application to spot and projection welders. Address Square D Company, 4041 N. Richards Street, Milwaukee 12, Wisconsin.*

SQUARE D COMPANY

1903 • **50** YEARS OF DESIGN LEADERSHIP • 1953

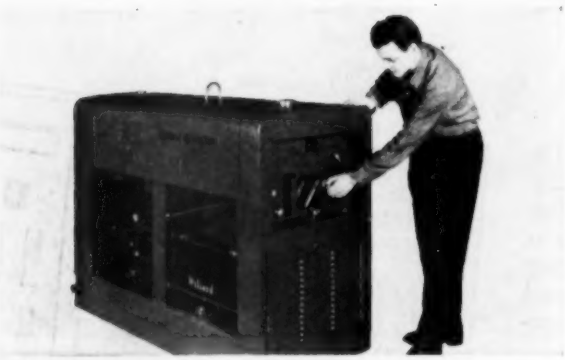
Welding Arcs

G-E MG WELDERS—half the size of other d-c welders of this type—offer a steady-arc interactor, single-dial dual control, easy inspection, wide current range, and high efficiency, for high production, operator satisfaction, low operating costs.

G-E AC WELDERS—best for 3 out of 4 jobs because of no arc blow—feature instant arc striking, steady capacitor-stabilized arc, exact current setting on the easy-to-read scale, high power factor for low-cost operation, and long-life silicone insulation.

FOR AC OR DC

Top performance, low over-all cost make G-E welders your best buy



G-E ENGINE-DRIVEN WELDERS—5 rugged types for every outdoor job—are powered by leading air- and liquid-cooled gasoline engines and diesels. Sturdily built to stand up in outdoor service, these units provide excellent welding performance.

Whatever the requirements of your welding job—whether it's AC or DC, indoors or outdoors—there's a General Electric welder available to give you unsurpassed performance. The features and operating benefits listed on this page can mean real savings for you during the long life of your G-E equipment.

You get more than just quality equipment when you buy G-E. Prompt shipment, application help, and complete service facilities provided by your local G-E Welding Distributor mean extra dollar savings for you.

For complete information on G-E welders and how they can help you do a better job at lower cost, contact your nearest G-E Welding Distributor today. He's listed here and in the classified section of your phone book under "Welding Equipment". General Electric Company, Schenectady 5, New York. 7105

You can put your confidence in—

GENERAL ELECTRIC

News

Information on equipment, electrodes and accessories from G.E., pioneer in arc welding

New G-E electrode nomenclature will simplify selection, stocking, training

To simplify electrode selection, stocking, and training, which have been complicated by the large variety of electrodes manufactured today, General Electric has put into effect a new mild-steel and low-alloy electrode nomenclature system. This new system, closely tied to familiar AWS classifications, can be explained by a simple example:

The G-E electrode formerly known as W-28 is an AWS Class E-6012 electrode. Under the new G-E system, this electrode will be known as W-612A, formed by adding "W" to the basic 6012 and, for simplicity, dropping the "0". The "A" is used to differentiate between this electrode and two other Class E-6012 electrodes (formerly W-29 and W-20F) which will now be termed W-612B and W-612C. All other G-E mild-steel and low-alloy electrodes will be designated in a like manner.

During changeover to the new system, G-E electrode packages will carry both old and new numbers. Nomenclature of G-E stainless-steel and hard-surfacing electrodes will not be altered.

To familiarize yourself with the new G-E electrode nomenclature, ask your G-E Welding Distributor for a copy of GED-1634A.

Copyright 1953, G.E. Company

Joe Magee says . . .

New W-610A electrodes reported 8 ways better

User reports on General Electric's new W-610A electrode list 8 performance benefits of this outstanding Class E-6010 rod.

They say W-610A . . .

- is easier, faster to use
- is free of "wandering arc"
- eliminates pinholing problems
- produces lower-porosity welds
- stops "fingernailing"
- has a stable coating
- prevents excessive spatter
- makes slag removal easy

Find out for yourself

If you haven't discovered these benefits for yourself, contact your General Electric Welding Distributor today. He'll give you a free sample of G-E Type W-610A—the electrode that's fast becoming the quality standard for the welding industry.

FREE

Stainless-steel Guide

If you weld stainless steel, you'll want this new G-E Bulletin "Welding and Metallurgical Aspects of Stainless Steels". Written for both the novice and veteran weldor, this easy-to-read pamphlet is full of practical data to help you select electrodes, produce better welds, and avoid common problems in stainless-steel work. Ask your G-E Welding Distributor for Bulletin GET-1955.

Here's the name of your G-E Welding Distributor—

Alabama: Birmingham—Alabama Oxygen, Young & Vann Supply; Mobile—Turner Supply

Arizona: Phoenix—Consolidated Welding Supply

California: Fresno, Los Angeles, Oakland, Sacramento, San Diego, San Francisco, Ventura—Victor Equipment

Colorado: Boulder, Colorado Springs, Denver, Durango, Ft. Collins, Ft. Morgan, Greeley, LaJunta, Longmont, Pueblo—Hendrie & Bolthoff

Florida: Hollywood, Miami—Florida Gas & Chemical

Georgia: Atlanta, Macon—Welding Supply & Service; Augusta—Marks Oxygen; Columbus—Williams Welding Supplies

Idaho: Boise—Olson Manufacturing

Illinois: Chicago, Moline, Morton—Machinery & Welder

Indiana: Evansville—Drill Master Supply; Ft. Wayne, Indianapolis—Sutton-Garten; South Bend—Perry Welding Sales & Service

Iowa: Des Moines—Machinery & Welder

Kansas: Coffeyville—Thompson Bros. Supply & Welding Equip.; Hutchinson—Kopper Supply

Kentucky: Louisville—Reliable Welding; Paducah—Henry A. Petter Supply

Louisiana: Alexandria, Shreveport—Hughes Oxygen; New Orleans—Consolidated Welding Supplies

Maryland: Baltimore—Arcway Equipment

Massachusetts: Boston—New England G-E Welding Sales Division

Michigan: Detroit—Welding Sales & Engineering; Grand Rapids—Miller Welding Supply

Minnesota: Duluth—W.P.&R.S. Mars; St. Paul—Production Materials

Mississippi: Jackson—Jackson Welding & Supply

Missouri: Kansas City—Hohenschild Welders Supply; St. Louis—Machinery & Welder

Montana: Billings—Valley Welders Supply; Butte, Great Falls—Montana Hardware

Nebraska: Lincoln—Lincoln Welding & Supply; Omaha—Baum Iron

New Jersey: Kenilworth—Welding Sales

New Mexico: Albuquerque—Industrial Supply Co., Hobbs—Western Oxygen; Las Cruces, Silver City—Car Parts Depot, Inc.

New York: Buffalo—Welding Equipment Sales; Syracuse—Welding Engineering & Equip.

North Carolina: Charlotte—Dixie Gases; Gastonia—Gastonia Motor Parts

North Dakota: Bismarck, Fargo—Acme Welding Supply; Fargo—Dakota Electric Supply

Ohio: Akron, Cincinnati, Cleveland, Columbus, Dayton, Mansfield—Burdett Oxygen; Toledo—Odland Iron Works

Oklahoma: Tulsa—G-E Welding Sales Division

Oregon: Eugene, Portland—J. E. Haseltine; Medford, Portland—Industrial Air Products

Pennsylvania: Philadelphia, Pittsburgh—Arcway Equipment

South Carolina: Columbia, Greenville—Welding Gas Products

South Dakota: Deadwood—Hendrie & Bolthoff

Tennessee: Chattanooga, Knoxville, Nashville—Welding Gas Products; Memphis—Delta Oxygen

Texas: Abilene—M&M Welding Supply; Alice, Corpus Christi—Crane Welding Supply; Alpine, El Paso, Marfa, Pecos—Car Parts Depot; Amarillo—Tex-Air Gas; Brownsville, Harlingen—Acetylene Oxygen; Dallas—Hill Equipment & Supply; Hereford—Tex-Air Gas; Houston—G-E Welding Sales Division; Lubbock—Welders Supply of Lubbock; Midland—West Texas Welders Supply; Odessa, Pecos—Western Oxygen; Plainview—Plains Welding Supply; San Angelo—Southwestern Welding Supply; Snyder—Western Welding Supply; Texarkana—Hughes Oxygen; Wichita Falls—Nortex Welding Supply

Utah: Salt Lake City—The Galigher Co.

Washington: Seattle, Spokane—J. E. Haseltine; Spokane, Yakima—Industrial Air Products

West Virginia: Bluefield—Bluefield Supply; Charleston—Virginian Electric; Huntington, Logan—Logan-Hardware & Supply

Wisconsin: Milwaukee—Machinery & Welder

Alaska: Anchorage—Northern Supply

Canada: Toronto—Canadian G.E.

Hawaii: Honolulu—American Factors, Ltd.

It may be used for manual-, dip- or mechanical-production soldering operations, either in powdered form as delivered or in molten form with equally satisfactory results.

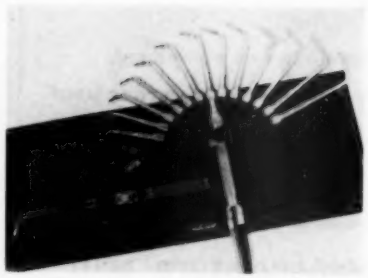
During several months of impartial tests by Battelle Memorial Institute, Aluma-Flux proved itself as a universal flux, equally effective for soldering stainless steel, bare and galvanized carbon steel, cast-iron and all other ferrous metals, copper, brass and nickel—all commercial metals commonly joined by soldering. The coating of copper with tin and the joining of unlike metals was also easily accomplished with Aluma-Flux.

Soldered joints in aluminum produced no corrosive action due to flux residue when exposed to salt spray, high humidity, alkaline water, etc. Neither was there any detrimental effect over protracted periods on the joined surfaces.

Aluma-Flux is being distributed nationally by Insulation and Wires, Inc., in convenient size metal containers. Complete technical and application data may be obtained by writing them at 3435 Chouteau Ave., St. Louis 3, Mo.

Aircraft Welding Torches

National Welding Equipment Co., 218 Fremont St., San Francisco 5, Calif., has placed on the market a torch of light weight and proper balance for the delicate



hand operations required in this type of welding. Torch needle valves are more easily adjusted while welding, and keep cool to the touch and do not cause flame distortion because of improper seating or inadequate valve stem support. Welding nozzles with accurately graduated orifice diameters achieve a full range of the needed flame sizes, and they are polished and chrome plated to retard slag adherence. Adequate provisions are made against overheated torch handle. A nozzle design permitting rotation of nozzle into any desired direction while welding and a multimixer that will take care of all flame requirements without popping or blowing are other advantages listed by the manufacturer. The skilled small aircraft parts or sheet metal welder will fully appreciate how such a torch will simplify his tasks and speed his operations.

An adequate and sturdy cutting attachment, Model 15, is provided for this Model 30 Welding Torch.

Industrial X-Ray Unit

A new NORELCO portable industrial X-ray unit (MG 160) that fits into the trunk of an automobile and is designed specifically for rapid inspection of welds, pipe lines, power plant, ship and aircraft equipment is available from the X-ray Department, Non-Destructive Testing Division, North American Philips Co., Inc., 750 S. Fulton Ave., Mount Vernon, N. Y.

The new unit is unique since the X-ray tube head also contains the high tension generator of 150,000-volt output. It weighs only 143 lb. The accompanying control is equally compact and weighs only 80 lb. The complete MG 160 equipment weighs only 223 lb.

The novel arrangement of tube and generator in one housing eliminates the need for high tension cables, always a possible source of trouble.

The X-ray tube is fan-cooled and has an end port which provides maximum usefulness in handling various types of "close-in" work. Combination tube and generator unit has a diameter of only 10¾ in. and is 35 in. long. Where desired, the diameter can be reduced to 8½ in. by eliminating the removable guards.

Power supply for the Philips MG 160 unit can be either 115 or 230 v, a-c. Current drain is 20 amp.

Arc Welder

An addition to the Miller Selenium Rectifier type d-c arc welders is the new Model SR-600 with a welding range 125 to 750 amp, manufactured by Miller Electric Manufacturing Co., Appleton, Wis. It is ideally suited for many of the automatic and semiautomatic welding processes constantly growing in popularity. All of the features of the Miller SR line have been retained in the new SR-600, giving the user the exclusive Miller advantages of "pulsating direct current" with its inherent higher deposit rate, greater arc flexibility due to the magnetic amplifier principle, greater power economy

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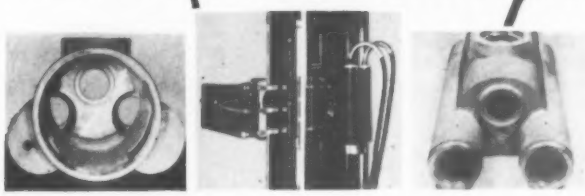

Previously Considered "Impossible", 11-Part Liquid-Proof, Shock-Proof X-Ray Assembly Now Welded for Maximum Strength, Safety

"Our X-Ray tube housing is fabricated from eleven different parts that are assembled and welded. This assembly is then immersed in water and tested to withstand 50 lbs., air pressure to insure against leaks or porous welds. After the tube is joined, the inside of the housing is lined with lead to imprison the dangerous X-Rays.

An additional factor that makes this such a difficult metal-joining problem is the extremely wide temperature range to which the housing is subjected. The tube, ordinarily remaining at room temperature when not in use, rapidly attains a heat of 215°F. in operation, making the use of solder impractical.

Test after test of welding alloys in various price ranges had failed in one or another of the requirements. One of the chief causes of failure was the high heat at which conventional welding alloys are applied. This high heat either melted the delicate threading on the fittings or required extensive aftermachining and finishing before the crinkle finish could be applied to the completed piece.

Finally EutecRod 190, the new EUTECTIC Low Temperature WELDING ALLOY, was recommended and tested — and met *all* requirements! Expensive finishing was eliminated due to the unique thin-flowing characteristics of the alloys. Because of the low heat of application, the threads remained unharmed, rejects were eliminated, and production speed increased enormously. Tensile tests definitely proved that the strength of the joint was multiplied many times over—while the actual *cost per job decreased!*

The day we first tested EutecRod 190 was an extremely profitable one for us!"

*–M-Laboratories, Connecticut**

*Full name and address on request.

Impossible? That's what the "M-Laboratories" thought, too, until they actually tried these new entirely different EUTECTIC Low Temperature. WELDING ALLOYS.® Then they came up with the astounding "Case History" shown on the left.

Yes, we not only *claim* this amazing performance — we *prove* that "EUTECTIC" is different . . . *prove* that these new alloys solve metal-joining problems where conventional materials fail!

Let us prove it in YOUR shop, just as we have in over 78,000 other plants and shops throughout America. There's no cost, no obligation involved. Just fill in and mail the coupon, below, for a FREE Consultation-Demonstration from one of our 350 trained District Engineers who stand ready to serve you from coast to coast. **Prove to yourself that there is something new and different in metal-joining . . .**

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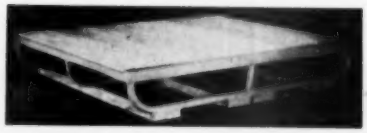
because of the high electrical efficiency plus all the other advantages generally associated with rectifier type welders. For those applications where power demands are in excess of these ratings, any number of SR-600's can be paralleled with ease.

The over-all dimensions of 27 x 32 x 50 in. result in the most compact 600-amp d-c welder ever designed, an important factor to consider in the pattern for more compact industrial plants. Simple electrical remote control allows the welder to be located at some distance from the work without sacrificing one bit of the flexibility of control.

In addition to a welding range of 125 to 750 amp, the Miller Model SR-600 has a rated output of 600 amp at 40 v, 60% duty cycle; primary volts 230/460; primary amperes 108/54; 34.5 kw; 43 kva; open-circuit voltage 70.

Welded Pallet

A new concept in pallet design is this Econoweld 555, a heavy-duty stacking-type pallet of all-welded steel and hardwood. Aimed at eliminating all maintenance and replacement costs due to fastener failure, the new Econoweld is assembled without a single fastener. Hardwood deckboards are held in a welded steel retaining frame. Through an ingenious

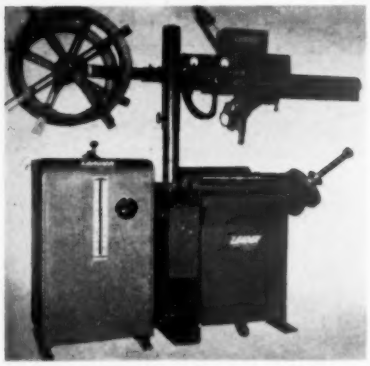


device, which the maker calls "Deckboard Lock," deckboards can be removed and replaced—by hand or with small hand tools—in a few seconds. Bottom boards are secured individually by "Nest Grips"—heavy-gage steel containers welded to the tubular skid runners. The pallet is priced competitively with the more serviceable types of heavy-duty wood pallets. The new product is manufactured by Econoweld Corp., 515 Callahan Building, Dayton 2, Ohio.

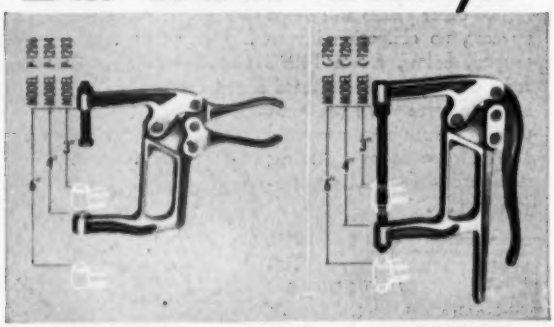
Automatic Welding Machine

Four important features that greatly increase its usefulness have been added to the model 550 Leader Automatic Welding Machine. These include a new, automatic self-adjusting, high-frequency arc starter and stabilizer device which has no moving parts and permits the use of low density current. Especially helpful is the new finger-tip controlled reversible, variable speed drive control for the work-handling motor. This simple unit operates without vacuum tubes, keeping maintenance to a minimum.

A new Acme-thread powered, horizontal arm lift makes arc positioning quick and almost effortless. New flux handling equipment includes a sight-feed flux hopper and an adjustable two-piece *caster-*



Six NEW Clamps



STIFFER—YET LIGHTER
REQUIRE LESS EFFORT TO CLAMP

Here is another forward step in KNU-Vise clamps for efficient, fast and secure clamping.

These six new clamps made of heat-treated steel forgings are stiffer, yet lighter, and require less hand effort to clamp. At the same time, a greater clamping force is obtained. In addition, the new hand-hold design of the C-Clamp (at right) provides a guard to protect the user's fingers while clamping. A second spindle, instead of the anvil, can be furnished for special applications.

Sales offices in principal cities. Teletype DE 49.

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A critical analysis of more than half a million dollars worth of research on the weldability of steels. Published by the Welding Research Council. More than fifty pages of tables on every type of ASTM, SAE, ABS and other carbon steels giving physical properties and recommended welding procedures for all thicknesses.

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Cleveland Ohio Oct. 19-23

mounted, flux bin which permits it to be used in conjunction with either rollers or positioner.

Features such as the step-over control for positive, manual operation, 4-in. transverse adjustment that permits exact positioning of electrode wire in relation to work centerline for all work diameters, and double reels for handling all types of wire are still standard equipment.

For prices and information on the model 550 Automatic Welding Machine write to Leader Welding and Manufacturing Co., 2418 Sixth St., Berkeley 2, Calif.

Shop Welders

The National Cylinder Gas Co., 840 N. Michigan Ave., Chicago 11, Ill., has redesigned its Sureweld A-C shop welders. The improvements, according to the company, provide better welding performance and greater ease of operation. The new design has also resulted in a lower selling price.

The Sureweld four-coil transformer has been redesigned so that the coils are positioned horizontally, resulting in better ventilation and cooler operation. No mechanical ventilation is required. Insulation has been improved by the use of double glass insulated magnet wire for primary and secondary windings.

The movable magnetic core section, which permits stepless current adjustment, has been positioned laterally, allowing the current control lever to be moved from the top of the case to the front. The lever, which requires relatively few turns to encompass the entire welding range, is placed directly under the calibrated current scale and the scale has been increased in size to facilitate accurate current settings.

Two models are available—one with a welding range of 25–295 amp, with and without power factor correction; the other with a range of 20–180 amp. The latter model meets REA specifications. Both models meet NEMA specifications and both are UL approved.

The Sureweld shop models are designed for maintenance, repair and light production welding, as contrasted with Sureweld heavy-duty industrial welders for high production welding.

Employment Service Bulletin

Positions Vacant

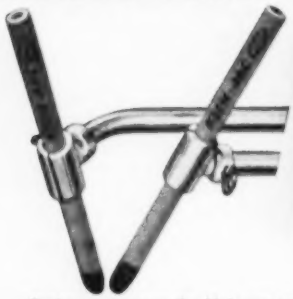
Wanted, two graduate assistants in welding department. Remuneration $1000 to $1350 for 12 hours per week of laboratory teaching. Write DeWitt Hunt, Industrial Arts Education, Oklahoma A. and M. College, Stillwater, Okla.

Services Available

Two young French graduate welding engineers, arc and resistance, some experience in jet production, seek positions any country. Write P. Baronnet, 68 Avenue des Gobelins, Paris 13e, France.

BECKER

KEEN-ARC CARBONS



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Designed to carry the high currents necessary for intense heat, BBB Keen-Arc Carbons produce a fine-grained weld of high tensile strength. They give a smooth, steady "flowing" flame which does not wander and which is concentrated at the desired focal point. Flame temperature is easily and accurately adjusted by merely changing the ampere input, and heavy copper coating permits gripping at extreme ends—eliminates frequent and periodic resetting.

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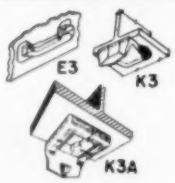

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Saxe Welding Connection Units position and secure structural parts to be welded.

Clip K3A permits an adjustable connection.

These widely used units eliminate all hole punching, and, with welding, produce the most economical, safe, and quickly erected structural frame.

Write for 1951 edition, Structural Welding Practice Manual.

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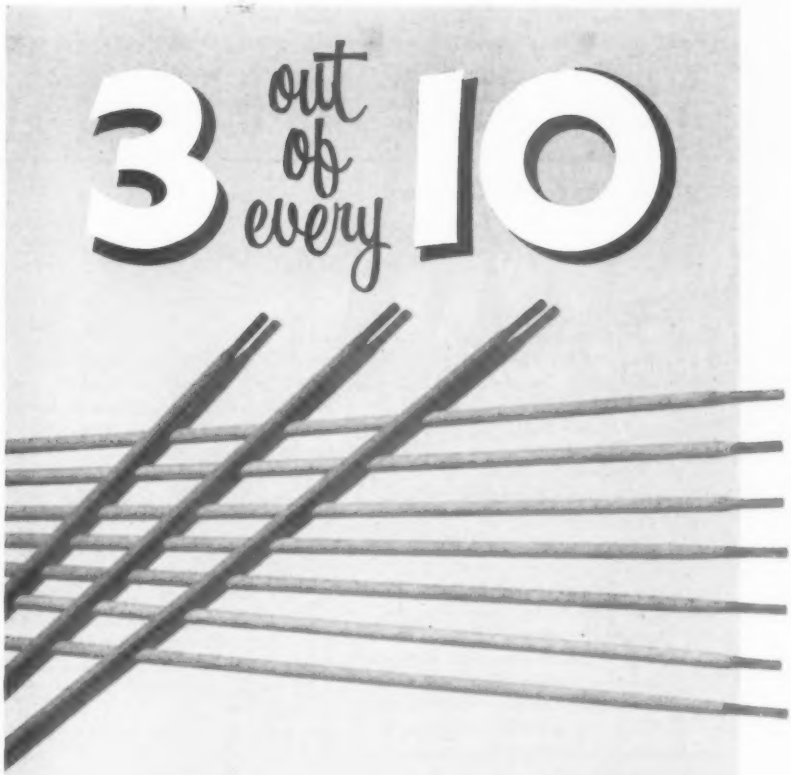

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Consistently through the years, users of stainless steel electrodes buy far more *Arcaloy* stainless electrodes than any other brand. Such outstanding popularity . . . such overwhelming acceptance . . . must be deserved! Approximately 3 out of every 10 stainless electrodes bought today are manufactured by Alloy Rods Company. Next time you buy stainless electrodes, be sure . . . buy *Arcaloy* from your Alloy Rods distributor. *For complete details request new Bulletin AR53-16.* Alloy Rods Company, York, Pennsylvania.

Manufacturers of *Bronze-Arc* phosphor bronze electrodes • *Nickel-Arc* and *Nickel-Arc 60* electrodes for cast iron • *Tool-Arc* electrodes for tools and dies • *Wear-Arc* hard-facing electrodes • *Weld-Arc* low hydrogen electrodes. Write for Bulletins on these products.

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SECTION NEWS AND EVENTS

as relayed to C. M. O'Leary

Spring Party

Bridgeport, Conn.—A combination introduction of newly elected officers and Spring Party was held by the *Bridgeport* Section on May 9th at Rapps Restaurant, Shelton, Conn., in the Surprise Room.

After a splendid buffet lunch complete with refreshments, entertainment in the form of male quartet singers and gymnasts thrilled the largest attendance of the season.

Inspection Trip

Buffalo, N. Y.—On April 23rd, 78 members of the *Niagara Frontier* Section were guests of the Westinghouse Electric Corp. for an inspection trip and dinner at the Cheektowaga Plant. The technical session was held in the plant auditorium, where H. J. Bichsel, [AWS], Design Engineer of the Westinghouse Arc Welding Division, discussed the "Design and Operating Characteristics of the Rectifier Welder."

Mr. Bichsel briefly traced the history of the rectifier-type welder. Initial experiments with copper oxide rectifiers were not successful. However, subsequent development of the selenium rectifier eliminated many of the previous difficulties and led to the development of the rectifier-type welder as we know it today.

Mr. Bichsel stated that this type of welder combines the rapid response associated with a-c transformers and the steady d-c current associated with motor-generator sets. Both rod burn-off rate and penetration are apparently the same for the rectifier welder and the motor-generator set. A number of slides were shown, comparing the static and dynamic characteristics of the two types of d-c welders. Mr. Bichsel also exhibited a series of color movies of welding arcs, taken at a speed of 3000 frames per second, which compared the operating characteristics of the rectifier welder and the motor-generator set.

Newly Elected Officers

Columbus, Ohio.—The *Columbus* Section announces the election of the following officers for 1953–54:

Chairman—Melvin C. Clapp, Battelle Memorial Institute

First Vice-Chairman—Arthur P. Bruce, American Blower Corp.

Secretary—Roger Zimpfer, Columbus Gas System Corp.

Treasurer—Joseph E. Brockmeyer, Surface Combustion Corp.

Director (for 1 year)—Geoffrey J. Siegel

Directors (for 2 years)—C. W. Ziegler, Roy B. McCauley, Jr., Carl J. Alff

Plant Visit

Columbus, Ohio.—Sixty-five members of the *Columbus* Section on April 10th visited the plant of the American Blower Corp. John Slemmons, District Sales Manager, gave an interesting rundown on the company's products and operations in general at the Columbus plant and other American Blower plants.

Annual Meeting

Columbus, Ohio.—The ladies were invited to dinner and dancing at Holiday Hill, Delaware, Ohio, on April 24th by the *Columbus* Section. Ninety-seven members and guests enjoyed the family-style dinners and 107 were present for the square and round dancing following dinner. Activities included ping pong, boating, games and cards.

Human Element

Dallas, Tex.—The May 6th meeting of the *Dallas* Section was held in the Recreation Room of the Mosher Steel Co. A nontechnical talk was given by Herbert W. Beutel, [AWS], of Mosher Steel Co., on "Human Relations and Its Part in the World of Today."

Diesel Locomotives

Dayton, Ohio.—Guest speaker at the April 14th meeting of the *Dayton* Section, held at the Engineers Club, was Delbert Porter, [AWS] Welding Engineer, Electromotive Corp., Cleveland, Ohio. His subject was "Welding Fabrication of Diesel Locomotives."

Mr. Porter's discussion was indeed informative and of great interest to this Section, witnessed by the second largest attendance this year. His discussion, illustrated with slides, began with receiving the steel at their plant and followed through the various phases of fabrication of the heavy members as well as the light metals to the completed Diesel locomotive.

A lively question-and-answer period followed and the meeting was dismissed to the coffee and donut period that followed.

Maintenance Welding

Denver, Colo.—A before meeting attraction at the May 13th meeting of the *Colorado* Section was the showing of a sound, color film, entitled "Pipe Line to the Clouds," through the courtesy of the Denver Board of Water Commissioners.

An excellent discussion on Maintenance Welding was given by C. C. Keyser, [AWS], of the Bethlehem Steel Co., Steelton, Pa.

Annual Ladies Night

Erie, Pa.—The Annual Ladies Night—Monte Carlo Party—held by the *Northwestern Pennsylvania* Section on May 12th was a highly successful evening enjoyed by all.

Opportunity Night

Hartford, Conn.—The March 12th dinner meeting of the *Hartford* Section held at the Rockledge Country Club was "Opportunity Night." Members brought in questions on all phases of welding. J. W. Mortimer, [AWS], of Whitlock Manufacturing Co., acted as Moderator.

After-meeting attraction was the showing of a film "The Shining Heart."

Plant Tour

Hartford, Conn.—Ninety-six members and guests of the *Hartford* Section took part in a tour of the Fore River Plant of the Bethlehem Shipbuilding Corp., Quincy, Mass., on the afternoon of April 9th, followed by dinner at the plant.

Before the tour a film on "Shipbuilding" was shown through the courtesy of the Bethlehem Shipbuilding Corp.

Quiz the Experts

Indianapolis, Ind.—A Quiz-the-Experts meeting of the *Indiana* Section was held on April 24th at the Antlers Hotel, Indianapolis. Ray Wirt was Moderator and

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FLOWLINE Welding Fittings are stocked throughout the country by leading warehouses specializing in corrosion-resistant metals, in Schedules 10, 40, and 80 (Schedule 5 also available)—sizes ½ inch through 12 inches—in stainless steel Types 304, 316, and 347; Monel, Nickel, and Aluminum.
With FLOWLINE Fittings it is practicable for users of corrosion piping to obtain the fullest economy and efficiency of simplified welded construction—in design, installation, operation, and maintenance.
Welded construction provides greatest freedom in designing the layout. The system uses less space, is lighter in weight, and can be assembled and put into service faster. It is permanently leak-proof, has greater strength, longer life, and best flow characteristics.
FLOWLINE corrosion-resistant fittings include tees, stub ends, ells, reducers, and caps. All are made of forged or wrought metals, cold formed by our exclusive process and annealed, putting the metal in the best condition for corrosion service.
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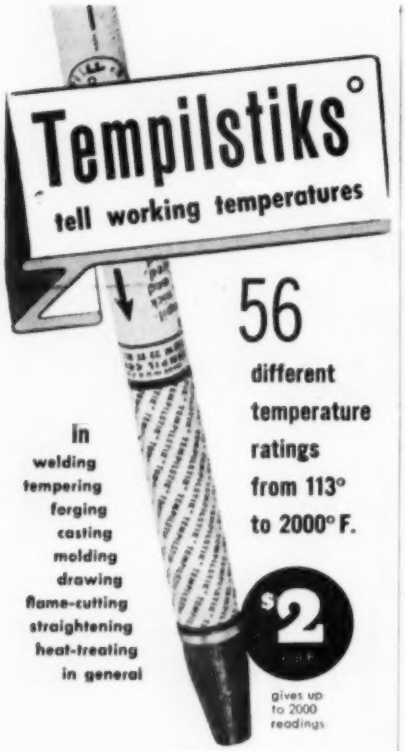

four very fine teams of experts representing other Sections competed for the trophy. Teams and experts were as follows:

Michigan Section—South Bend, Ind.
Harry Hale
Lloyd Ebert
Donald Kyler
George Fetherston

Dayton Section—Dayton, Ohio
Major Paul Marking
Clarence Shulthers
Earl Garber
R. Appenzeller

Anthony Wayne Section—Ft. Wayne, Ind.
Harry Johnson
George Laws
Carl Gaby
K. H. Zimmerman

Detroit Section—Detroit, Mich.
Larry Kendall
Fred Kops
Robert Burch
Frank Boucher

Several rounds of questions were fired at the teams covering all phases of welding. The teams worked hard and the grading was close. The Detroit team edged out Anthony Wayne by the slim margin of only ten points. Ninety-one members and guests enjoyed the meeting.

Election of Officers

Long Beach, Calif.—The *Long Beach* Section announces the election of the following officers for 1953–54:

Chairman—Charles Breese, John Tillman & Co.
First Vice-Chairman—O. B. Bowers, Bowers Ambulance Service
Second Vice-Chairman—Bill Williams
Secretary-Treasurer—Frank Pope, Pacific Welding Supply Co.
Recording Secretary—J. J. Carl
Chairman, Membership Committee—Bill Williams
Chairman, Program Committee—O. B. Bowers

Bronze Electrodes

Louisville, Ky.—The April 28th meeting of the *Louisville* Section was opened by a report from Mason Noyes, Section Technical Secretary, covering the latest approved uses of brazing filler metals. This is one of the most important accomplishments of the AWS and is described in the new A5.8–52T specifications.

The main address was given by F. E. Garriott, [AWS], Manager, Weldrod and Wire Department of Ampco Metal, Inc., Milwaukee, Wis., covering the use of bronze electrodes in joining copper-base alloys, iron-base alloys, dissimilar metals and overlay welding for bearings. In addition he covered the use of bronze wire with the inert-gas consumable-electrode method for joining and overlaying applications.

Election of Officers

Louisville, Ky.—The following are the newly elected officers for 1953–54 of the *Louisville* Section:

Chairman—Roba Yarbro
First Vice-Chairman—Everett S. Elwood
Secretary—Elmer H. Dilley
Treasurer—Jos. O'Regan
Chairman, Membership Committee—E. F. Schulz
Chairman, Program Committee—Everett S. Elwood
Technical Representative—Mason Noyes

Jet Engine Alloys

Newark, N. J.—The last meeting of the 1952–53 season of the *New Jersey* Section was held at the Essex House on May 19th. A very thorough presentation on the welding of jet engine alloys including numerous slides of the jigs, fixtures and tooling needed to weld components for jet engines was given by guest speaker Alan Busto, Welding Engineer, Solar Aircraft Corp. The clear presentation of this subject by Mr. Busto was very well received by approximately 65 members and guests present. Prior to this presentation a colored movie was shown through the courtesy of the Bethlehem Shipbuilding Co. The picture concerned the problems and difficulties that were overcome in converting a victory ship to the fastest Great Lakes ore carrier. The most interesting phase of the picture was scenes of this ship being moved up the Mississippi River through bridges that barely permitted it to squeeze through.

Winner of the free dinner was William Dolan of the Foster Wheeler Co., Carteret, N. J.

The final arrangements for the annual picnic, to be held in September, were completed.

At the conclusion of the meeting F. O. Bodine of the Midwest Supply Co., turned over the Section Chairmanship to Nick Kiernan of the Metal & Thermit Corp. Mr. Kiernan presented Mr. Bodine with a past-chairman pin and acknowledged the excellent job performed by Mr. Bodine during the past season as chairman of the New Jersey Section.

Annual Stag

New York, N. Y.—The Annual Stag Dinner Meeting of the *New York* Section was held on May 8th at the Building Trades Club, bringing to a close a successful year for the Section. As usual, this dinner meeting was exceptionally well attended with the SRO sign displayed several weeks in advance.

At the meeting the results of the elections for the 1953–54 season were announced, and the new officers installed, as follows:

Chairman—S. T. Walter, Air Reduction Sales Co.
First Vice-Chairman—W. E. G. Lucas, Taylor Forge & Pipe Works
Second Vice-Chairman—J. Mikulak, Worthington Corp.
Secretary-Treasurer—E. W. Axthelm, Linde Air Products Co.

In the fall of 1952 the Section published its first Year Book in which all members of the Section are listed.

A very successful Lecture Course, consisting of six lectures on Welding Metallurgy was presented during the year. A. W. Zeuthen, [AWS], of Socony Vacuum Oil Co., was the lecturer. A total of 120 persons were enrolled in the course.

A total of eight technical meetings were held during the year on a diversity of subjects. A new innovation was the "Job Shop Welding Clinic" held as the November 1952 meeting at which a panel of four answered practical questions from the audience. The panel was made up of prominent local job shop operators.

It is with profound regret that the Section reports the death of G. L. Baker on May 2nd. Mr. Baker was Sales Manager for Welding Products in the New York area for the Westinghouse Electric Corp., and served as Chairman of the New York Section from 1950 to 1951.

Welding and Distortion Control

Pascagoula, Miss.—An extemporaneous discussion of the subject "Welding and Distortion Control of Light Structures" was given by Arnold V. Walker, owner of Arnold V. Walker Shipyard, Pascagoula, Miss., at the May 6th meeting of the *Pascagoula* Section.

A sound color film entitled "Inland Voyage" was shown through the courtesy of the Bethlehem Steel Corp.

Ladies Night

Phoenix, Ariz.—Over two hundred members and guests of the *Arizona* Section had a most enjoyable time at the first Ladies Night held at Bud Brown's Barn on May 9th. It was a dinner-dance and was such a success that the Section is planning to have a Ladies Night annually in the future.

Heliarc Welding

Phoenix, Ariz.—R. J. Frick, Sales Engineer, Linde Air Products Co., addressed the May 20th meeting of the *Arizona* Section on the subject "Heliarc Welding Process." Mr. Frick's background made possible a presentation which was very well received and informative. He presented the latest developments of the Heliarc Process and indicated its great possibilities in welding difficult metals in various positions.

Election of Officers

Phoenix, Ariz.—A past-chairman pin was presented at the May 20th meeting of the *Arizona* Section to the outgoing Chairman, Ralph Smith, and the gratitude of the Section was extended to him for his fine services and leadership the past year.

The results of the annual election were announced as follows:

Chairman—Charles Fogwell, Haywire Welding Works
First Vice-Chairman—J. August Rau, Allison Steel Mfg. Co.
Second Vice-Chairman—William (Bill) Fisher, Lincoln Electric Co.
Secretary—Walter Riley, Riley and Foltz, Consulting Engineers
Treasurer—F. Morris Aspey, Consolidated Western Steel Div., U. S. Steel Corp.
Executive Committee (two-year term)—Paul V. Bawn, Lee Crawford, William McDowel, Don Walker
Executive Committee (one year to serve)—John Dyer, E. H. Allison, K. B. Rousseau, W. T. Garland, Phil Binkley, Ralph H. Smith

Tri-State Conference

Pittsburgh, Pa.—The Sixteenth Annual Tri-State Welding Conference, sponsored by the *Pittsburgh* Section and the Engineers Society of Western Pennsylvania, was held on Friday evening, April 24th, and was a big success with over four hundred in attendance.

The program opened with the Annual Dinner with Toastmaster Dale McFeatters, Director, Information Service, Westinghouse Electric Corp. Introductory remarks were made by Fred L. Plummer, AWS President and Director of Engineering, Hammond Iron Works, Warren, Pa.; D. S. Keenan, President, Engineers Society of Western Pennsylvania and President of Carnegie Natural Gas Co., Pittsburgh; and John H. Blankenbuehler, AWS District No. 4 Vice-President and Design Engineer, Hobart Co., Troy, Ohio.

Dinner speaker was W. W. Sproul, Jr., Vice-President, Manager, Special Products Division, Westinghouse Electric Corp.

Entertainment included "This is Gonna Be Diffrunt" presented by Radio Artists Entertainment Service.

Officers Elected

Pittsburgh, Pa.—The following are the officers elected by the *Pittsburgh* Section for 1953-54:

Chairman—W. H. Kauffman
First Vice-Chairman—Leonard R. Constantine
Secretary-Treasurer—J. F. Minnotte, Minnotte Bros. Co.
Chairman, Membership Committee—John D. Ruschak
Chairman, Program Committee—Joseph W. Keohoe
Technical Representative—Donald H. Marlin

Jet Engines

Saginaw, Mich.—The regular monthly dinner meeting of the *Saginaw Valley* Section was held on May 14th at the High Life Inn, with an attendance of 65. The Bowery Boys Male Quartette of the Industrial Brownhoist Corporation entertained the members with an interesting musical rendition.

"Problems Related to Fabrication Materials Used in Jet Engines" was the subject of an excellent presentation given by H. E. Schultz, AWS, General Electric Co., Lockland, Ohio.

Student Symposium

St. Louis, Mo.—Up-to-date welding information was given engineering students from Washington University, Missouri School of Mines, University of Missouri and the University of Illinois at a Welding Symposium, May 2nd. Staged in Louderman Hall on the Washington University campus, it lasted from 9 A.M. to 1 P.M. and was sponsored by the *St. Louis* Section. Neil Stueck, of Stupp Bros. Bridge and Iron Co., was in charge of the program as educational chairman for the section.

The meeting was opened by Henry M. Reitz, assistant professor of civil engineering and Mel Lischer, Section Chairman. First speaker was W. C. Henzlik, AWS, Associate Editor of *The Welding Engineer*, who spoke on the history and present scope of welding. Howard N. Simms, AWS, Chief Metallurgist and welding engineer for Black, Sivalls and Bryson, Oklahoma City, Okla., next spoke on welding research and possible future developments.

A panel discussion on "What Welding Means to Industry" was ably led by Carl Weber, Director of Research and Engineering for Laclede Steel Co. His panel members included Jay Law, AWS, District Engineer, American Institute of Steel Construction; John Patton, AWS, Plant Metallurgist, General Steel Casting Co.; Philip H. Smith, AWS, Sales Group Department Head, Nooter Corp., and Arthur R. Parsons, Chief Engineer, St. Louis Ship Building Co.

Closing item on the morning program was the General Electric Co. film, "Arc Welding at Work."

Field Trip

San Francisco, Calif.—Through the courtesy of the Pacific Gas and Electric Co. and the Bechtel Corp., 69 members of the *San Francisco* Section visited the

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new Contra Costa Steam Plant at Antioch on April 27th. This 400,000-hp plant involves one of the largest installations of high-pressure steam piping ever undertaken in this area. The latest and most modern welding procedures were followed by the contractor—the Bechtel Corp.

Russell G. Rhoades, AWS, Welding Engineer for the Bechtel Corp., was scheduled to present a short talk, but was suddenly called out of town. Robert Olson, Welding Engineer for the same company, substituted for Mr. Rhoades. A message of welcome by Mr. Rhoades was read in his absence.

Welding and Cutting

San Francisco, Calif.—Sgt. Robert Gremminger, Traffic Education Detail of the San Francisco Police Department, gave a timely and inspiring talk on the current traffic accident situation, at the dinner which preceded the regular monthly meeting of the *San Francisco* Section held on May 25th at the Engineers Club.

At the technical meeting three excellent 20-min talks were given as follows:

Charles Robinson, AWS, Special Technical Representative of Air Reduction Pacific, discussed the various gas mixtures used with the gas-shielded arc-welding processes.

Wesley Hillendahl, Service Engineer of Linde Air Products, discussed a new method of metal removal under the title of "Powder Washing of Ferrous and Nonferrous Metals."

George Lambrix, Engineering Department of Victor Equipment Co., had as his subject "Pressure Regulator Operation" which covered a brief discussion of common construction principles as well as actual functioning and characteristics of pressure-reducing regulators.

Annual Meeting

Schenectady, N. Y.—The *Northern New York* Section's Annual Meeting held May 15, 1953, in Albany, and attended by 43 members, was a highly enjoyable stag affair featuring bowling before dinner, a short business meeting after eating, presentation of awards in both serious and humorous veins and an evening of general informality.

Humorous Awards at Northern New York Section Meeting

Seven past-chairman's pins were presented by Chairman I. W. Johnson, to past chairmen who have ably led the Section and who still continue their interest in Section Activities. These men are H. S. Swan, E. F. Spittler, E. F. Potter, R. W. Clark, R. T. Gillette, C. M. Rhoades, Jr., and W. J. VanNatten.

Awards in a humorous vein were planned and presented by R. A. Gilbert, Awards Chairman, to R. W. Clark, I. W. Johnson, J. A. Gowan, J. P. Frandsen, R. M. Rood and D. C. Herrschaft, respectively, for eminent performances, as story teller, slope-control exponent, judge at "Stump-the-Experts" Meeting, publicity director, prolific parent and as newest member.

Election of Officers

Seattle, Wash.—Election of officers for the *Puget Sound* Section took place at their May 14th dinner meeting held at the Engineers Club with the following results:

Chairman—L. M. Crawford
First Vice-Chairman—L. B. Zylstra
Secretary—D. R. Coles
Executive Committee—R. L. LeBlanc, Sidney K. Smith, R. Miller, Lloyd Hayward, R. Herman

Speakers at the after-dinner meeting were Frank Donnelly, Project Engineer in charge of Construction of the University of Washington's Cyclotron, and Engineer for the Trane Co. Mr. Donnelly told the story of the U. of W.'s 60-in. cyclotron, how it is built and what it will do. John Dickinson, AWS, Process Service Engineer for The Linde Air Products Co., discussed "Inert Arc Welding of Heavy Aluminum Sections."

Heat Flow

Sheffield, Ala.—The *Tri-Cities* Section held a dinner meeting at the Muscle Shoals Hotel, Apr. 30, 1953.

J. H. Patterson, Project Manager of Southern Constructors, Wilson Dam, Ala., gave an animated talk on the advantages of being a member of the AWS.

The speaker of the evening was H. Kuenzel, Head of Mechanical Engineering, University of Alabama. His talk dealt with temperature distribution and heat flow when a weld is being made and the resultant metallurgical changes that occur in metal. He also illustrated with slides the various points in his talk of every-day experiences.

Refreshments were sponsored by Mr. Patterson.

Newly Elected Officers

Sheffield, Ala.—The *Tri-Cities* Section announces the election of the following officers for 1953–54:

Chairman—J. L. York
First Vice-Chairman—R. L. Ahearn
Secretary—L. C. Garrett
Chairman, Membership Committee—F. S. Wells and T. Green

Advertising Rates

The Welding Journal

Effective March 1, 1953	1 time	3 times	6 times	12 times
Full Page	$255.00	$235.00	$220.00	$200.00
Two-thirds Page	180.00	165.00	155.00	145.00
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Business and Social Meeting

South Bend, Ind.—The final meeting for the 1952–53 season of the *Michiana* Section was held at the Chain-O-Lakes Conservation Club on May 21st. After a general business meeting, officers for the following year were announced as follows:

Chairman—Erwin Laylin
Vice-Chairman—Donald Kyler
Secretary—W. G. Fassnacht
Treasurer—J. A. Miller
Executive Committee—G. Schneider, J. Robinson, W. Bushman

Social session followed. Bingo was the order of the day, the object being one of the many door prizes furnished by a number of friends of the Section. Refreshments were also served and an enjoyable evening was had by all.

Welding of Tools and Dies

Toledo, Ohio.—Approximately 30 members and guests were in attendance at the April 9th meeting of the *Toledo* Section when the regular meeting convened at 8 P.M. in Linck's Cafeteria. A goodly share of the group had gathered earlier for the dinner at 6:45 P.M.

Frank E. Kessler, [AWS], ably assisted by Al Woodward, [AWS], of the Welding Equipment and Supply Co., presented an illustrated talk on the applications of welding techniques to the fabrication of composite dies, salvage of worn and broken tools and dies, and emergency repairs of tool and die components. Mr. Kessler covered the many factors involved in determining the practicability of a salvage operation, such as repair cost versus replacement cost; time and cost of remachining; availability of replacements; life of repaired component versus replacements, etc. He pointed out the importance of knowing the heat treatment of a component when attempting to select the proper material and technique, since matching the steel analysis is of much less importance than matching the original heat treatment. The importance of preheat and postheat treatment was also brought out with the caution that the processing temperature should never exceed the draw temperature given the piece originally.

Heliarc Welding

Tucson, Ariz.—A television program on station KOPO-TV preceded the regular dinner meeting of the *Tucson* Section held on May 19th in the Fiesta Room of the Santa Rita Hotel.

The television program was a round table discussion with George Hunt, [AWS], Tucson High School, as Moderator. His panel consisted of Henry Warren, Stoody Co., Robert J. Frick, Linde Air Products, and Paul Ballenger, [AWS], El Paso Natural Gas Co. Each series of questions and answers by the panel led to one of the four live demonstrations of welding, cutting and silver soldering operated by various members of the Section. The main theme of the program was "Welding and How It Affects the Life of the Man in the Street."

After the 25-min television program, the regular dinner meeting was held. The main speaker was preceded by a humorous coffee talk by Henry Warren of the Stoody Co.

Robert J. Frick, Linde Air Products Co. gave an interesting discussion of Heliarc welding. Following his talk he showed the latest Alcoa film on "Inert Arc Welding of Aluminum Alloys." The next regular monthly meeting is planned for September 15th.

Pressure Vessels

Tulsa, Okla.—Forty-five members and guests of the *Tulsa* Section heard an excellent address on "Pressure Vessels" given by R. A. Davis, [AWS], of the Chicago Bridge and Iron Co. at the May 4th meeting of the Tulsa Section.

Election of Officers

Warren, Ohio.—The *Mahoning Valley* Section announces the election of the following officers for the 1953–54 season.

Chairman—J. H. Cordner, Westinghouse Electric Corp.
First Vice-Chairman—W. D. Colbert, Chicago Bridge & Iron Co.
Secretary—G. C. Fogg, National Cylinder Gas Co.

Rectifier Welder

Wichita, Kans.—The April 13th meeting of the *Wichita* Section started with a plant tour of the Aircraft & Automotive Products Co., followed by dinner and a meeting. G. K. Willecke, [AWS], Miller Electric Mfg. Co., presented an illustrated talk on the Rectifier D-C Welder. Mr. Miller is the co-designer of the Miller rectifier welder.

Maintenance Welding

Wichita, Kans.—A tour of the Kansas Gas and Electric Murray Gill Steam Electric Plant preceded the May 11th meeting of the *Wichita* Section. After the plant tour, the meeting was turned over to C. C. Keyser, [AWS], Welding Engineer, Bethlehem Steel Co., who presented a nontechnical talk on the applications of the different types of welding in the steel plant, with special emphasis on the use of the submerged arc process in maintenance work.

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abstracts of CURRENT WELDING PATENTS

Prepared by V. L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington, D. C.

2,636,725—Flame-Hardening Apparatus—Manley R. Nelson and Richard S. Sheehan, Denver, Colo.

This flame-hardening apparatus includes a hydraulic cylinder with a piston rod extending therefrom and a burner head secured to the piston rod. Adjustable pressure-regulating means are provided in the system for regulating the rate of piston travel.

2,636,965—Flash Welder with Variable Secondary Impedance—Joseph H. Cooper, Warren, Ohio, assignor to The Taylor-Winfield Corp., Warren, Ohio, a corporation of Ohio.

Cooper's patent relates to electric resistance-welding apparatus wherein a pair of work-holding clamps make electri-

cal contact with workpieces to be welded and conductors connect to such clamps with at least one of the conductors having a variable inductive means therein for impeding the flow of welding current. The variable inductive means comprises a loop having spaced parallel side portions and means to connect the side portions at two or more points so that two or more impedance characteristics can be derived from the inductive means.

2,636,966—Die Spacing Means for Welding Apparatus—Melvin M. Seeloff and Robert Anderson, Warren, Ohio, assignors to The Taylor-Winfield Corp., Warren, Ohio, a corporation of Ohio.

In this patent, an electric resistance flash-butt welding apparatus is disclosed and it has fixed and movable work-holding platens. The apparatus also includes first and second upset cylinders for moving the movable platen toward and away from said fixed platen. Special gage-type abutment plates are associated with the upset cylinders to aid in controlling the action thereof.

2,636,967—Gas-Shielded Electrode Holder for Arc Welding Torches—Andre Bassot, Boulogne-sur-Seine, Elie Daynie, Neuilly-sur-Seine, and Alain de Sancy, Paris, France, assignors to L'Air Liquide, Society Anonyme Pour L'Etude et l'Exploitation des Procedes Georges Claude, Paris, France.

In this patent an inert gas-shielded arc-welding torch having an electrode of refractory metal is disclosed. A gas chamber is at the end of the torch and terminates at one end by a gas outlet around the electrode. The patent relates to special gas discharge members in the electrode holder.

2,637,279—Welded Railway Car Truck Frame—Edward J. Charlton, Coatesville, and Lewis W. Edwards, Lancaster, Pa., assignors to Lukens Steel Co., Coatesville, Pa., a corporation of Pennsylvania.

A railway truck frame having reinforcing plates welded to the transition member of the frame is covered in this patent.

2,637,798—Apparatus for Welding a Terminal Clip to a Wire—James S. Burge, Floyd J. Foust, Willard C. Shaw and Warren M. Rider, Anderson, and Hilton J. McKee, Middletown, Ind., assignors to General Motors Corp., Detroit, Mich., a corporation of Delaware.

A machine for use in the manufacture of electric condensers having an insulated lead extending from an enclosing can is covered by this patent. The machine includes a conveyor, and a solenoid for controlling operation of the electric welder at a welding station for welding a terminal clip previously assembled with a lead to the condenser lead. Means are present in the apparatus for feeling a condenser in the workholder at the welding station, and an electric circuit is provided for connecting the solenoid with the electric current welding source. This circuit includes two switches in series with one switch being under control of the feeler mechanism and remaining closed if a condenser is present in the workholder, and means also are provided for causing operation of the feeler means and to cause the closing of the other switch to produce a cycle of welder operation if a condenser is present. The apparatus also provides for actuation of the conveyor after the weld cycle.

2,638,524—Welding Process and Apparatus—Amel R. Meyer, Griffith, Ind., assignor to Graver Tank and Mfg., Co., Inc., East Chicago, Ind., a corporation of Delaware.

Meyer's welding process is for use on an upstanding shell and its process includes the steps of holding the ends of a deformable longitudinally extended strip to the ends of a horizontal area of the shell. An intermediate portion of the so extended strip is deformed toward the shell and is pressed against the portion of the shell regardless of horizontal curvature and irregularities in the shell. A layer of flux is poured onto the portion of the strip contacting the shell, and the shell is horizontally traversed with the welding arc submerged under the flux.

2,638,525—Welding Stud and Method of Arc Welding—Albert M. Candy, La Grange, Ill., assignor, by mesne assignments, to National Cylinder Gas Co., Chicago, Ill., a corporation of Delaware.

This patent relates to the arc welding of a stud to a plate and it includes the step of placing a stud provided with an aluminum element carried by and extending beyond the terminal surface of the end of the stud, and completing an electrical circuit between the stud and a part through the aluminum element to form an arc upon melting of such aluminum element. The thickness and spacing of such element with respect to the stud is so selected as to form a welding arc upon being melted. Such melted aluminum provides a flux to protect molten metal formed by the arc from oxidation, and lastly the end of the stud is forced into contact with the part to which it is to be welded in order to interrupt the arc and form a weld.

2,638,665—Method of Welding Stainless Steel—Prentiss S. Viles, Baytown, Tex., assignor, by mesne assignments, to Standard Oil Development Co., Elizabeth, N. J., a corporation of Delaware.

Viles's welding method relates to welding chrome-nickel stainless steel and it includes the steps of applying a mixture of a welding flux containing elementary sulfur in an amount in the range of between 0.25 and 25% by weight to two adjacent boundaries of bodies of such steel. Then the adjacent boundaries of such metal are welded together in the presence of such welding flux mixture.

2,638,854—Welded Corner Post Assembly—James E. Candlin, Jr., Chicago, Ill., assignor to Pullman-Standard Car Manufacturing Co., Chicago, Ill., a corporation of Delaware.

A special railway car corner post assembly is disclosed in and covered by this patent.

2,638,972—Torch—Warren A. Sparks, Long Beach, Calif., assignor to John M. Henry, Los Angeles, Calif.

This novel torch includes a flint and a striker for igniting the gas in the torch. The patented torch includes means for first sparking the flint to ignite acetylene in the burner tube and then a second tube in the torch is opened to admit oxygen to the burner tube.

2,639,361—Timer for Welding Systems—Edward C. Hartwig, Tonawanda, and Robert F. Barrell, Buffalo, N. Y., assignors to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

This patent relates to an apparatus for controlling a welding system wherein welding electrodes are provided, a starter is present for actuating the electrodes to close, and a contactor is provided for controlling the current flow through the electrodes. The apparatus includes a squeeze timer connected to the starter for causing the contactor to transmit current through the electrodes a predetermined time interval after actuation of the starter, while a weld timer is present for timing the duration of the current flow. A hold timer is provided for timing the interval during which the electrodes are in engagement, and the apparatus is connected for initiating the timing operation of the weld and hold timers substantially simultaneously.

2,639,362—Article for Welding Stainless Steel—Prentiss S. Viles, Baytown, Tex., assignor, by mesne assignments, to Standard Oil Development Co., Elizabeth, N. J., a corporation of Delaware.

This patent relates to the method of patent number 2,638,665 and it covers a welding rod of nickel, chromium and iron. This rod has a coating flux thereon with between 0.25 and 25% of elemental sulfur therein. The weight ratio of the coat to the rod is in the range of between about 1:2 to 1:4.

2,639,363—Welded Joint of Dissimilar Metals—Paul M. Brister, Madison, N. J., and Lambert F. Kooistra, Akron, Ohio, assignors to The Babcock and Wilcox Co., New York, N. Y., a corporation of New Jersey.

This patent relates to apparatus for treating a welded joint between dissimilar metal tubular conduit members with different thermal coefficients of expansion. Means are provided for uniformly heating the welded joint between the members by electrical resistance heating elements uniformly spaced apart circumferentially completely around the tubular conduit members and arranged to heat the portions of the tubular conduit members radiantly adjoining the weld. Other means connect the alternate heating elements around the circumference of the joint in a first electric circuit and the heating elements intermediate such alternate heating elements in a second electric circuit in parallel with the first electric circuit.

LIST OF NEW MEMBERS

Effective May 1, 1953

ANTHONY WAYNE

McDaniel, Bruce J. (B)

BIRMINGHAM

Feigelson, Herschel (C)
Lane, Ronald E. (B)
Lowery, Ernest E. (B)
Thompson, Edward (B)

BOSTON

Burke, Lawrence S. (B)
DeGiso, Carmen (B)
Hodgkins, Richard E. (C)
Lawless, Richard J. (C)
Travis, Charles (C)
Williams, John H. (B)

CHICAGO

Bredzs, Nikolajs (C)
DeCecco, Nickolas A. (C)
Lebret, George L. (C)
Loeffler, Howard J. (B)
Meyer, Herbert M. (C)
Reedy, Lone O. (C)

CINCINNATI

Wallace, Bruce H., Jr. (B)
Whelan, Charles T. (B)

CLEVELAND

Cella, Charles P. (C)
Forbes, Fred W., Sr. (B)
Lukat, Arthur E. (B)
Mulligan, Robert C. (B)

COLUMBUS

Bovie, David F. (D)
Fletch, Eddie J. (C)
Korona, Marion W. (D)

DALLAS

Hefner, C. E. (B)
Lindsey, R. L. (B)

DETROIT

Bixby, Duane Kenneth (B)
Cheger, Michael, Jr. (B)
Conachen, Gerald (D)
Ettinger, Bruce L. (D)
Fox, Kenneth A. (C)
Griffith, Arthur Thomas (D)
Guidot, Charles A. (B)
Hinz, Arthur C. (C)
Johnson, Marvin (D)
Kane, Gordon L. (D)
Koss, Gerald G. (D)
Lamphear, Gerald R. (B)
Lee, Joseph H. (D)
Moxlow, William (B)
Packard, Ivan E. (C)
Perkins, Charles L. (B)
Pon, Henry (D)
Repen, Edward J. (D)
Roman, John (C)
Ross, Stuart T. (C)
Rotta, Joseph C. (B)
Schwartz, Arthur (D)
Shreeman, Samuel (D)
Smith, J. K. (B)
Smith, S. H. (B)
Swartz, R. E. (B)
Szlachetka, Vince (D)
Teahan, Jerry (D)
Watkins, Robert T. (B)
Werner, John R. (B)

EAST TEXAS

Barnes, William T. (D)
Ormsby, Thomas F. (B)
Prentice, Bruce (D)
Zuercher, L. O. (C)

HOUSTON

Carter, Melvin J. (C)
Dick, Charles M. (B)

INDIANA

Bossingham, H. E. (B)
Prah, Harry F. (B)

IOWA

Jacox, Frederick (B)
Reisenbigler, Walter (B)
Stellrecht, Milo (B)

LEHIGH VALLEY

Shepherd, Richard F. (C)

LONG BEACH

Causey, Charles R. (B)
Coleman, Russell P. (C)
Stricker, E. B. (C)

LOS ANGELES

Anderson, Henry A. (C)
Bell, Eric C. (C)
Courter, Jess Gilbert (C)
Deris, Lloyd J. (B)
Evans, Herbert B. (B)
Hackbarth, Alvin K. (C)
Hemmel, C. B. (C)
Komes, Jerome W. (B)
Michelsen, J. A. (B)
Newman, W. W. (C)
Nota, Albert P. (C)
Reynolds, R. S. (C)
Simpson, Charles B. (B)
White, Smith G. (B)
Winters, Fred E., Jr. (C)
Wolverton, Bruce (B)

MAHONING VALLEY

Harrington, Paul E. (B)
Jeffries, Herbert C. (B)
Stowe, Walter (C)

MARYLAND

Cooke, Randolph B. (C)
Wood, Charles C. (C)

MILWAUKEE

Kedrowski, Dan (B)

NEW JERSEY

Deitrich, John A. (B)
Putman, Laurel E. (C)
Sproul, Walter E. (C)

NEW YORK

Berry, Charles W. (B)
Donovan, Louis J. (C)
Leahy, Joseph M. (C)
Leszak, Edward (B)
Sherwood, Allan N. (B)
Whitelaw, Daniel (B)
Whitney, David W. (C)

NIAGARA FRONTIER

Hock, James J. (C)
Watson, Harold N. (B)

NORTHEAST TENNESSEE

Barnes, George, Jr. (B)

NORTHERN NEW YORK

Deitz, Leroy (C)
Herrschaft, Donald C. (C)
Klingler, Werner William (C)
Wawrousek, Hans (D)
Young, Hadley E. (C)

NORTHWEST

Jobes, Lawrence R. (B)
Olson, Herbert E. (C)

PASCAGOULA

Casey, N. J. (C)
Colle, J. H. (B)
Dumont, Arthur, Jr. (C)
Foster, L. Walker (C)
Frederic, V. H. (C)
Fuller, R. L. (C)
Guest, William R., Jr. (B)
Halasz, Nandor V. (C)
Hudgins, Herman Nelson (B)
Johnson, W. C. (C)
Ricker, Charles H. (C)
Rowe, John R. (B)
Sanchez, J. A. (C)
Steele, George L. (C)
Sullivan, J. A. (C)

PHILADELPHIA

Civitello, Nick (B)
Fox, William W., Jr. (B)
Frakes, Paul V. (B)

PITTSBURGH

Albright, Alvin T. (C)
Darko, Steve (A)
Landerman, Edgar (C)
Martin, William A. (C)

SALT LAKE CITY

Thompson, Eldon C. (B)

SAN FRANCISCO

Jeffrey, Richard S. (C)
Marion, Gerald R. (B)

SANGAMON VALLEY

Clinton, Edward C. (B)
Wood, Robert J. (B)

SUSQUEHANNA VALLEY

Basala, Alex (C)

TOLEDO

Fitch, Alfred E. (B)

TRI-CITIES

Durkin, Jack (B)
Mays, N. Leslie (C)
Wilson, James W. (B)

TUCSON

Arvizu, Manuel M. (B)
Borchers, Orrell E. (B)

TULSA

Saner, Carl (B)
Wies, L. A. (C)

YORK-CENTRAL PENNSYLVANIA

Sacco, Columbus (B)
Wilson, Walter B., Jr. (B)
Zehnder, Frank J. (C)

NOT IN SECTIONS

Croswell, A. M. (B)
Madsen, Karl Kristian (B)
Tinker, Theron Earl (C)

Members Reclassified

During the month of May

PHILADELPHIA

Sutton, Herbert (C to B)

(*Continued from p. 633*)

tion. Accordingly, it is doubtful whether the SOCIETY will be able to issue new Official Speaker and Motion Picture Directories until along about the fall of this year.

Therefore, for the time being, it is requested that all Sections continue to use the Official Speakers' and Motion Picture Directories issued to them and in the possession of their Chairmen and Secretaries, as previously mentioned and as issued under dates of June 15 and Aug. 15, 1952.

New Directories will be sent out as soon as possible. When they are issued it is not advisable to destroy the old ones but rather it is expedient to retain them in the file because they more than likely contain names of speakers who have not approved of their names being listed in the subsequent Directory but who, upon a proper approach from a Section, may still be willing to appear and present their subjects.

Greater consideration must be given on the part of the Section Program Chairman to preparing his program for the succeeding year well in advance. In view of the fact that AWS speakers are furnished through the courtesy of industry with no charge to the Section or the National Society, it follows that in order to sustain the cost of such activity, industry must have well in advance the request for speaker appearances so that the speaker's program can be arranged to provide him the greatest amount of time when he is in a city to engage in other activities that will be of benefit to his company and help to defray expenses. Too frequently it is assumed by the membership that the speakers who appear before our Sections are under obligation to do so. Such is not the case. The SOCIETY is greatly indebted to industry for this service. It is a contribution on the part of industry toward the SOCIETY and its Sections' welfare and the greatest appreciation must at all times be shown to organizations providing speaker service, as well as to the individual speakers who not only give time away from their company business but also from their private home activities.

Swiss Acetylene Society

The Annual Report of the Swiss Acetylene Society for 1952 records a good business year for the welding industry in Switzerland. Acetylene and oxygen sales were up 10% and competition from foreign electrodes was less intense. Despite pessimistic predictions, the market for arc-welding generators and transformers has not reached saturation. Competition in the export market, particularly South America, became much keener, with Germany being the chief competitor. The output of resistance welders fell due to lower domestic and export demand.

The membership of the Society remained about constant at 1255. The Society gave 27 welding courses, attended by 440 students. The welding magazine totaled 250 pages. The Society library now has 1483 publications on welding, 108 films and 1000 lantern slides. The testing and inspection activities went on as usual. The "Gas Welding" section of a welding dictionary in ten languages has been completed and will be issued this year.

INDEX TO ADVERTISERS

Air Reduction	Outside back cover
Alloy Rods Company	667
The American Brass Company	647
American Chain and Cable Co.	652
American Manganese Steel Division	657
Arcair Company	671
Aronson Machine Co.	646
Becker Brothers Carbon Co.	666
The Champion Rivet Co.	658
Crucible Steel Company of America	653
Dockson Corporation	640-641
Drawalloy Corporation	635
Eutectic Welding Alloys Corporation	663
General Electric	660-661
Hobart Brothers Company	579
The International Nickel Company, Inc.	655
Jackson Products	Inside back cover
Lapeer Mfg. Co.	664
The Lincoln Electric Company	651
Linde Air Products Company, A Division of Union Carbide and Carbon Corporation	582
P. R. Mallory & Co., Inc.	581
Metal & Thermit Corporation	580
National Carbide Company	650
National Metals Exposition	665
Page Steel and Wire Division	652
The Reid-Avery Company	649
Square D Company	659
Stulz-Sickles Co.	662
A. O. Smith Corp.	645
Sylvania Electric Products, Inc.	639
Tempil® Corporation	670
Tube Turns, Inc.	643-644
Tweco Products Company	Inside front cover
Union Carbide and Carbon Corporation Linde Air Products Co.	582
United States Testing Company, Inc.	666
Victor Equipment Company	584
Welding Fittings Corp.	669
Weldwire Company, Inc.	654
J. H. Williams & Co.	665

WELDING RESEARCH COUNCIL

of the Engineering Foundation

Sponsored by the American Welding Society, American Institute of Electrical Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Civil Engineers, American Society of Mechanical Engineers, Society of Naval Architect and Marine Engineers, American Society for Metals and American Society for Testing Materials

Supplement to the Welding Journal, July 1953

Current Welding Research Problems

The purpose of this compilation is to provide university research workers with a list of current welding research problems and to provide Project Committees with suggestions as to the needs of Industry. These suggestions have come largely from Industry

STUDENTS and staff members of technical and scientific schools and universities frequently come to the Welding Research Council requesting suggestions for research. To fill this need and to provide its Project Committees with suggestions, the Council canvasses industry at intervals of two years or so. The canvass is intended to bring to light the subjects on which technical representatives of industry would like help. The suggestions from the canvass are sent to a committee of welding researchers for review. The present list is the product of the latest convass.

The suggestions for research are listed under five main headings:

I. Welding Physics and Chemistry
II. Welding Metallurgy
III. Mechanical Properties and Testing
IV. Structural and Design
V. Resistance Welding

Each heading should interest the following college departments:

I. Departments of Physics, Inorganic Chemistry and Physical Chemistry
II. Department of Metallurgy
III. Department of Mechanics and Materials Testing
IV. Department of Civil Engineering
V. Department of Electrical Engineering

Many of the problems can be investigated without welding equipment. Some require considerable outlays of time and equipment, but most can be subdivided or enlarged to suit the limitations of time and equipment of any research worker, short term or long term.

The central office of the Welding Research Council, 29 W. 39th St., New York 18, N. Y., often can assist in outlining detailed research plans for anyone interested in one or more of the problems on the list. Sometimes, the Council can assist in supplying specimens and grants-in-aid. It is important to plan well ahead of the time at which the research can be started, because of unavoidable delays in delivery of specimens and appropriation of money. Planning should cover as many phases of the problem as possible in order to ensure that individual projects may contribute to a unified picture of the problem as a whole. A comprehensive and adequate investigation of any problem frequently requires a series of student investigations, properly coordinated by an enthusiastic professor. The publication of progress reports of which the professor is co-author tends to rouse the interest of representatives of industry and to accord recognition to the university and professor.

To those universities who have been affiliated with the University Research Committee of the Council for periods up to thirty years, the utility of the list of suggested problems and the advantages of affiliation with the Committee are well known. To those who are not familiar with the unusual opportunities afforded to welding researchers by affiliation with the Committee, one of its most important activities may be described.

A conference of University Research Professors is held each year during the National Metal Congress and Exposition. The Council makes available funds to pay for railroad and pullman expenses of professors who attend, with an upper limit of fifty dollars to any one professor or research worker. There is thus provided an opportunity for a university research worker to discuss his problems with leaders of industry and with other research workers in the field.

Through close connection with the AMERICAN WELDING SOCIETY, opportunity is provided for the presentation of a completed piece of research in the form of a paper at the National Meetings of the SOCIETY either in the Spring or the Fall. Even though the paper may not be presented, an opportunity is provided for its publication in the *Welding Research Supplement*. This *Supplement* accounts for about half the technical text pages of THE WELDING JOURNAL, which reaches scientific workers throughout the world.

The extent of the participation of universities in welding research, and the problems which engage their attention, may be grasped from the following tabulation of titles of research reports from universities published during 1952 in the *Welding Research Supplement*. The subjects of the reports are subdivided into the five groups of suggested problems. For ready reference, the page number of each report also is listed. A study of these papers should give rise to ideas for further research. The fact that there were only a few more than twenty reports from universities during the year (less than one-third of the *Supplement* pages) accentuates the need for increased research activity.

I. Welding Physics and Chemistry
   - (*a*) Basic Flame Studies (465-s)
   - (*b*) Inert Gas Shielding of Metal Arcs (582-s)
   - (*c*) Brazing Hydromechanics (310-s)

II. Welding Metallurgy
   - (*a*) Strain Rate, Twinning and Fracture (475-s)
   - (*b*) Porosity in Weld Metal (381-s, 406-s)

III. Mechanical Properties and Testing
   - (*a*) Low-Temperature Stress Relief (233-s, 393-s)
   - (*b*) Dimensional Effects in Fracture (20-s)
   - (*c*) Brittle Strength and Transition Temperature (515-s)
   - (*d*) Stress Concentrations under Cyclic Load (273-s)
   - (*e*) Repeated Load Tests (238-s)
   - (*f*) Stresses in Circular Patch Specimens (402-s)

IV. Structural and Design
   - (*a*) Welded Continuous Frames and Their Components (205-s, 543-s, 607-s)
   - (*b*) Straightening Structural Members in Place (257-s)
   - (*c*) Welded Reinforcement of Openings in Structures (169-s)

V. Resistance Welding
   - (*a*) Spot Welding Titanium Alloys (469-s)
   - (*b*) Contact Resistance (457-s)
   - (*c*) Projection Welding Heavy Gages (113-s)
   - (*d*) Seam Welding 0.005-In. Inconel (366-s)

I. WELDING PHYSICS AND CHEMISTRY

Research in the physics and chemistry of welding falls into two categories:

1. Research on welded products.
2. Research on welding processes, or welding operations.

This list of Suggested Research Problems in Physics and Chemistry is subdivided into these two classes. It has been compiled partly from previous lists and partly from new suggestions. In a few instances, several collaborators have sent suggestions for research on the same subject. To preserve the outlook of each collaborator, each suggestion has been included in the list.

Basic to most research on welding operations and welded products are the thermal constants of commercial metals at high temperatures. The compilation of a table of constants and coefficients for commercial metals up to arc temperatures is suggested as a research problem of the first importance. Unfortunately, many of the thermal data for the table have not been determined. Consequently, researchers on thermal studies of welding are handicapped at the outset.

Suggestions for Research on Welded Products

(Refer to the separate sections on "Structural and Design" and "Mechanical Properties and Testing" for additional suggestions.)

1. One of the questions confronting industry is the effect of residual stresses on performance of welded steel structures. There is very little information as to what effect residual stresses induced by welding may have on the mechanical properties of steel, and whether such stresses affect the transition from ductile to brittle behavior. This might be a study that would interest the Plasticity Committee.

2. The influence of welding variables upon heating and cooling rates, and the possible influence of these heat flow relationships upon subsequent distortion and/or internal stresses in the weldment. Such a study would be particularly valuable if directed toward an analysis of the stainless steels and nonferrous metals.

3. A theoretical and experimental study of the resistance to high velocity application of stress, of different weld metals and combinations of plate and weld metal.

4. The quantitative determination of the distortion effect of various welding deposits, including the cumulative effect of small passes; relative effect of large versus small passes; the effect of high speed versus low speed, etc. While the general effect of these variables is known, the quantitative evaluation of their effect in

both directions, longitudinally and transversely to the weld, would be of real practical value.

Another problem frequently encountered is the necessity of avoiding distortions in salvage welding. *Example:* Building up of main bearing bores or large areas on the cylinder blocks. All presently available techniques require extreme care or skill, and excessively long labor time. Any methods giving a satisfactory job with less labor and less skill would be useful.

5. Corrosion of weldments: Subjects for research on the corrosion of welded structures are suggested by H. R. Copson in THE WELDING JOURNAL, **32,** 90-s to 91-s, February 1953. Three factors are important: (*a*) The joint metal may differ in composition from the base metal or the base metals may be dissimilar, (*b*) the metallurgical structure varies across the joint and (*c*) there may be high residual stress. A few of Copson's suggestions may be mentioned here.

In neutral solutions, the electrochemistry of the corrosion of steel should be studied, with emphasis on the potentials of local anodes and cathodes, the area ratios and the polarization curves. In acid solutions, more needs to be known about hydrogen overvoltage. What determines whether the hydrogen will enter the metal or will be evolved as gas?

A satisfactory simple means is needed for establishing when complete cathodic protection is attained. Quantitative data also are needed relating the corrosion factors of the environment (temperature, aeration, velocity, pH, dissolved salts, galvanic couples, time, etc.) to the minimum current for total protection. Similar information is needed on inhibitors.

The theory and mechanism of stress corrosion cracking need further development with detailed knowledge of the influence of internal structure, the magnitude and distribution of stresses and the influence of the environment. What is the role, if any, of hydrogen in stress-corrosion cracking? The whole subject of hydrogen damage in aqueous solutions needs further study, particularly where it ties in with the cracking of pressure vessels.

Suggestions for Research on Welding Processes

Each major welding process has many subdivisions. For example, gas welding may be subdivided into air-acetylene welding, oxy-acetylene welding, oxy-hydrogen welding and pressure-gas welding. Likewise cutting may be subdivided into oxygen cutting, lance cutting, powder cutting and arc cutting, each of which, in turn, has numerous subdivisions. A researcher familiar with any of the processes knows that he can ask questions about the physics and chemistry of each process that experts cannot answer. Frequently the researcher has the mental and experimental facilities the expert lacks to approach the problems posed by his process. For this reason, it is believed that, if the researcher will familiarize himself with the details of any given welding process and break down the process into its physical and chemical variables and occurrences, the research problems that he can attack will suggest themselves to him naturally.

(A) Resistance Welding

(Refer to the separate section on "Resistance Welding.")

1. Contact resistance: The development of the fundamental theories that affect contact resistance.

(B) Arc Welding

1. Mechanism of metal transfer in the welding arc: Development of instruments and techniques for the observation and measurement of metal transfer in the iron-iron welding arc, a classification of types of metal transfer and evaluation of factors controlling metal transfer.

2. Steady-state properties of heavy-current welding arcs: Evaluation of temperature in the arc column, potential drops at the surface of the electrodes, current density in the arc column and at the electrodes, potential gradient in the arc column, heat produced in the arc column and at the surfaces of the electrodes with arc current, atmosphere, pressure, metal vapor and coating constituents as parameters.

3. Arc stability and methods of stabilizing arcs: Study of the various stabilizing circuits with parameters of voltage gradient in the arc column, ionization potential of the arc atmosphere, current density and arc current, electrode materials and configuration, thermal time constant of the arc atmosphere, the recombination and diffusivity of electrons and ions in the arc atmosphere, the supply of vapors and gases from electrodes and coatings.

4. The heating of metals by a rapidly moving electric arc: The effect of moving the arc at speeds varying from 500 or 600 to several thousand feet per minute should be studied.

5. The influence of metal conditions upon the welding arc: The characteristics of the welding arc as functions of ionization potential of the metal vapor, the vapor pressure and rate of vapor production, the melting and boiling points, the thermal conductivity, the heat of evaporation, the temperature of the metal, and the geometry and cooling characteristics with refractory and readily vaporized electrodes.

6. Heat transfer mechanism between the arc and metal surfaces: Study of the electrode potential drop to within a micron of the surfaces of the electrodes as to physical state, power converted into heat, heat transfer laws, melting and vaporization of electrode metal, state of particles in the arc atmosphere at the electrodes, and electrical properties of this region. Also the heat transferred to the electrodes by conduction, convection, diffusion and molecular dissociation.

7. High-current phenomena in arcs between electrodes other than carbon: Volt-ampere characteristics at currents in the positive-slope region, anode and cathode drop characteristics, elucidation of the current-

carrying mechanism, current density, and potential distribution in the main arc stream and in the cathode and anode drops, determination of the percentage of heat dissipation by radiation, convection, conduction and molecular dissociation, determinations of temperature distribution in the arc stream, determination of the effect of various atmospheres and pressures on the arc, and the effect of magnetic stabilization.

8. An extension of Froome's cathode-spot current-density study to steady-state arcs: Fundamental information on spot mechanism could be obtained with cathode-ray and Kerr cell photographs.

9. Theoretical treatment of electron emission by a very high-temperature plasma under the influence of an electric field, as basis for a reasonable theory of the cathodic processes in metal arcs: Work should include investigation of temperature concept. Essentially a theoretical investigation the results of which could be checked against known experimental data.

10. Ionization of the arc: An exploration of the nature of the ions contributing to the conduction in arcs of various types would be valuable. The most attractive problems are:

(*a*) Source of charged carriers, whether electrode, base metal, coating or shield.
(*b*) Influence of the shield on the discharge.
(*c*) The nature of arcs using various metal electrodes. A great deal of work has been done or is planned, but parallel researches are desirable in this vast field.

11. The characteristics of low-hydrogen electrodes should be further investigated. Why do some European-made electrodes seem to exhibit better weldability and allow higher welding speeds and easier slag removal than the low-hydrogen electrodes produced in this country?

12. The nature of "diffusible" and "nondiffusible" hydrogen in steel welds should be further investigated. Some authorities believe that the quantity of diffusible hydrogen is inversely proportional to the iron-oxide content of the weld metal. Others feel that this is more closely related to microfissures, porosity and inclusions present in the weld. Since diffusible hydrogen seems to be far more important than nondiffusible hydrogen, further investigation of the differences is advisable.

13. Studies should be made to determine the susceptibility of electrode coatings to moisture absorption under various atmospheric conditions of temperature and relative humidity. Whereas many studies have been made of the weld metal resulting from conventional and low-hydrogen electrodes, little attention seems to have been directed to finding out how the various electrodes should be handled in storage and in use to avoid the troubles which might arise from moisture pickup. The relation of this characteristic of the coating to the chemistry of the coating is a fundamental factor and little seems to have been published on this subject. Some information relative to proper methods of the restoration and drying of electrode coatings would also be valuable. Excessive drying is detrimental to some electrodes, such as the cellulose types, where it may result in severe porosity. What is the mechanism for this?

14. An oscillographic and spectrographic study of striking an arc: A quantitative method is required for determining ease of arc striking with an investigation of the following variables: a-c versus d-c superimposed high-frequency striking current, open-circuit voltage, composition of atmosphere, nature of striking surface and composition of coating on the electrode.

15. Electric conductivity and surface tension of welding slags up to arc temperatures with particular reference to submerged arc welding.

16. An exploration of arc action, including visible length, short circuits and type of metal transfer, over wide ranges of current and voltage: The well-known standard covered electrodes should be studied as well as submerged arc welding. For submerged arc welding the electrode might be immersed in a crucible of liquid flux above the metal before current is turned on. Current-voltage determinations might be made with increasing gap between metal and rod (see paper by C. E. Jackson and A. E. Shrubsall, THE WELDING JOURNAL, **29** (5), 231-s to 241-s (1950)).

17. Problems in inert-gas arc welding: (*a*) Effect of metal vapor in inert-gas-shielded arcs: How much vapor exists in the arc plasma and what is its effect on voltage gradient? If possible, develop theory predicting observed values.

(*b*) Arc voltage: Relative portions of arc voltage due to plasma, cathode region, and anode for wide variety of currents, current densities, materials and shielding gases. This study would provide a basis for further theoretical development of the atmospheric arc and would lead to better understanding of wire burn-off and plate melting in welding.

(*c*) Determination of deionization time in atmospheric arcs: Variation of time with gas shield, current and other variables.

(*d*) Effect of gas shield on transfer phenomena using bare wires: Motion pictures of transfer and theoretical deduction of mechanism involved to reduce spatter in welding.

(*e*) Arc radiation losses: Measure radiation loss from inert-gas-shielded arc.

(*f*) The effects of small amounts of impurities in inert gases upon the characteristics of an electric arc: This investigation should study the effects of impurities of the order of less than one-half of one percent.

(*g*) Accurate information is required on alloy transfer characteristics across the inert-gas-shielded metal arc in order to assist the fabricator in the specification of filler wire and base metal suitable to this process.

18. Cooling rates: There have been very extensive studies in this field from the viewpoint of weldability. There are, however, some problems which require further study:

(*a*) Influence of high currents and speeds on cooling rates and weld contours.

(*b*) Extension of measurements and calculations to other metals, such as stainless steel and aluminum.

19. Slag metal relationships in the submerged arc welding of stainless steels and nonferrous metals: It would be of value to determine the effect of flux composition upon alloy transfer across the arc, and the effect of flux blanketing upon cooling rates directed toward a final understanding of their influence upon the useful life of the weldment.

(*C*) *Gas Welding and Cutting*

1. A study of the variation of the composition of the weld metal as a function of the flame adjustment and welding atmosphere in oxy-acetylene welding.

2. A study of the causes of sparking in gas welding with plain carbon and low-alloy steel rods.

3. A study of the origin of drag lines in oxygen-cutting and the effect of nonturbulent oxygen jets.

(*D*) *Pressure Welding*

1. The pressure welding of commercial metals, similar and dissimilar combinations, should be studied to determine the effect of the following variables:

(*a*) Degree of plastic deformation required to secure a weld.

(*b*) Effect of the rate of application of pressure.

(*c*) Role of recrystallization, if any.

II. WELDING METALLURGY

A thorough understanding of the status of our knowledge of the metallurgy of welding, that is, what we know and what we do not know, is an important foundation for effective advances in the solution of unsolved problems.

The publication this year of the Welding Research Council's *Monograph on Weldability of Steels* provides a unique survey of this field and is highly recommended to those contemplating research in the metallurgy of ferrous welding. For supplementary study the chapter on "Fundamentals of Welding Metallurgy" in the current edition of the WELDING HANDBOOK, and the Metallurgy section of the article on Current Welding Research Problems in the June 1951 *Welding Research Supplement* to THE WELDING JOURNAL are also recommended.

(*A*) *Ferrous Welding*

1. A systematic study of the factors influencing hot cracking of both ferritic and austenitic weld metals: This should include:

(*a*) A survey of atom size, melting point, crystal structure and diffusibility of solute elements and compounds in relation to the solvent iron. (See Rollason-Bystrom paper, *Jnl. Iron Steel Inst.*, **169**, 347–352 (1951).)

(*b*) The nature, origin and path of hot cracking and the influence of welding procedures. (See Apold paper, *Welding Research*, **6**, 55r–62r (1952).)

Note: (*a*) and (*b*) should be undertaken initially as an analysis and interpretation of existing data, to be followed by such experimental programs as may be needed to confirm or disprove the most important indications from (*a*) and (*b*).

2. The interrelation of carbon, oxygen, nitrogen and hydrogen in the loss of ductility and fatigue strength of mild steel weld metal when rapidly cooled from below 800 F to room temperature: Why is hydrogen generally detrimental in metal arc welding and relatively harmless in atomic hydrogen welding? (See Flanigan papers in THE WELDING JOURNAL, 1950–52 and Rollason-Roberts paper, *Jnl. Iron Steel Inst.* (October 1950).)

3. The cause of porosity in high-sulfur weld metal: Review of pertinent published information, particularly the Apold paper, *Welding Research*, **6**, 55r–62r (1952). Experimental investigation comparing E45XX with E6010 and E6015 weld metals with both high- and low-sulfur base metals, and including nature of slag and inclusions, and analysis of evolved gases.

4. The influence of welding processes with wide differences in ratio of rate of heat input to heat dissipation (e.g., spot, manual metal arc, and submerged arc) on the mechanical properties of the heat-affected zone of high-strength steels whose strength results from heat treatment or cold work before welding.

5. A study of the characteristics, causes and prevention of the diffusion of carbon from a carbon or low-alloy steel into a higher chromium steel bonded by welding and exposed to temperatures above 800° F: Compare by welding directly and after "buttering" with a barrier metal.

6. Study of the cause and prevention of porosity in rimmed steel welded by the inert-gas-shielded arc process.

7. A basic study of the influence of metal composition, temperature and pressure on the solubility and diffusion rate of hydrogen in ferritic and austenitic weld metals and heat-affected base metals.

8. Determination of the solubility and diffusion rate of nitrogen in relation to composition, temperature and pressure of ferritic and austenitic weld metals.

9. Why are cold cracks transcrystalline in some instances, intercrystalline in others or a combination of both types? What is the critical or threshold value of hydrogen necessary to cause cracking under various conditions of stress and for various compositions? What is the influence of the direction of applied stresses upon the orientation and nature of hydrogen cracks? Some studies might attempt to determine the role of hydrogen in promoting embrittlement in martensite under circumstances where no visible cracking occurs. Is cracking due to high internal hydrogen pressures just below a threshold of cracking so that moderate super-

imposed stresses cause failure to occur in a brittle manner?

10. Application of the experimental techniques of isothermal and cooling transformation diagrams to the response of steels to the high-speed thermal changes encountered during welding: Consideration should be given to brief austenitizing periods, to various cooling rates and to isothermal temperature effects. Extension of such curves down to at least 200° F is needed in view of the fact that the cooling rates in this range are of much greater importance than heretofore believed. (See Miller, *et al.*, paper in THE WELDING JOURNAL, **29,** 450-s (1950), and Apblett, *et al.*, paper, *Ibid.*, **29** (9) 421-s (1952).

11. A study of the weldability of nodular graphitic cast iron, with the ultimate aim of developing improved welding procedures.

12. A comparison of the relative susceptibility to formation of sigma phase in austenitic weld metals and base metals of the same nominal compositions, and study of the causes of any significant differences.

13. The influence of composition, structure and prior mechanical and heat treatment on the behavior of austenitic chromium-nickel-columbium (Type 347) steel in:

(*a*) Inert-gas-shielded arc welding with nonconsumable electrode.
(*b*) Inert-gas-shielded arc welding with consumable electrode.
(*c*) Metal arc welding.

14. Further basic studies of the mechanism and means of obtaining the essential benefits of stress-relief heat treatment of weldments by alternative procedures such as preheat, low-hydrogen electrodes, etc.

15. Study of slag-metal interactions in fusion welding: See Claussen paper in THE WELDING JOURNAL, **28,** 12 (1949) and Welding Research Council, *Bull. No. 15*, January 1953.

(*B*) *Nonferrous Welding*

1. A study of the cause of hot shortness associated with silicon in welds of nickel alloys and the role of columbium in counteracting it.

2. A study of the metallurgy of joining dissimilar metals by various welding methods.

Examples of current interest are:

(*a*) Cross wire welding of very fine tungsten or molybdenum wires to somewhat larger nickel or nickel-plated steel wires.
(*b*) Spot welding of carbonized or oxidized nickel or conventional nickel-plated steel.
(*c*) Welding of small tinned copper wires to electrical apparatus terminals.
(*d*) Welding of permanent magnets, such as Alnico, to steel bases.
(*e*) Welding of thin sections (0.005–0.020 in.) of nonferrous to ferrous metals and alloys.

3. Correlation of metallurgical and other factors controlling the abrasion resistance of overlay weld deposits.

III. MECHANICAL PROPERTIES AND TESTING

The investigation of weld joint mechanical properties is complicated by the fact that three separate material zones interact to determine the over-all performance. The interpretation which must be made of test, or research studies, accordingly requires consideration of the interplay of the intrinsic mechanical properties of the weld, the heat-affected zone and of the base material. In great part the past research effort has been aimed either at investigations of the intrinsic properties of specific zones or at the development of weld joint evaluation tests. Relatively little effort has been directed to a dual approach involving studies of the performance of practical weld joints with controlled properties, i.e., with known variations of the properties of specific zones. Because of this gap it is difficult to apply the data concerning properties of specific zones to the practical problem of the performance of weldments in service.

The engineer desires a simple test which will provide an integrated index of weldment performance. In a purely objective sense such a test may be recognized as entailing the simultaneous evaluation of base material, heat-affected zone and weld metal quality. It is of foremost importance that the feasibility of this request be determined. Research should be directed to determine the factors which determine the intrinsic properties of heat-affected zones and welds with the further aim of resolving the extent to which the mechanical properties of these zones determine the performance of the base material. The common term "detrimental effect of welding on the properties of the base material" is misleading for it connotes that the base material properties are changed; actually, the only change is in the stress condition which the base material must withstand. A weld region which develops a crack fault effectively changes the stress conditions imposed on the base material from simple, or biaxial tension, to highly triaxial tension. The over-all problem may be summarized to the following principal elements:

(*a*) *Base Material.* Performance is dictated by the sensitivity of the base material to the presence of sharp cracklike faults developed at weld zones. It should be recognized that this phase of the base material problem bears no relation to welding and accordingly may be investigated separately.

(*b*) *Heat-Affected Zone.* Performance is dictated by the effect of the weld thermal cycle on the mechanical properties of the base material. This phase of the base material problem is related to welding conditions, base material characteristics and to a certain degree to electrode characteristics.

(c) *Weld.* Performance is dictated by electrode composition, coating characteristics, base metal composition and welding procedures.

The Base Material Problem

The most basic problem confronting the research investigator is to determine the fundamental laws which govern the sensitivity of steels to the presence of sharp crack faults. The effects of temperature and rate of strain on the tolerable limit of deformation preceding the initiation of brittle fracture should be investigated. The effects of temperature and stress level on the propagation characteristics of brittle fracture present further problems. It appears that fracture initiation is determined by a ductility transition entailing the inability of the metal to develop minute amounts of deformation at notch tips; fracture propagation is determined by an energy balance between the requirements for fracture continuation and the available elastic strain energy. The propagation of brittle fractures may be stopped by entry of the crack into regions of low stresses. It would be important to determine if the energy for fracture propagation could be expressed in absolute terms.

From a viewpoint of the immediate engineering needs it is important to establish the level of notch ductility as determined by conventional notch-bend specimens which will assure that the initiation and propagation of fractures will be prevented in service. Basically this entails establishing the significance of notch-bend specimen transition data. It is known that fracture propagation is possible through material which will not permit fracture initiation. The National Bureau of Standards investigation demonstrated that "source" plates were characterized by lower notch ductility as compared to "through" plates at the temperature of ship fractures. Inasmuch as large welded structures include material of various quality characteristics, it is important to establish if the design criteria should be based on eliminating only the poorest material which is potentially of "source" type, or on eliminating material which is potentially of "through" type. Conversely, the use of high-quality materials at critical positions and/or along the path of possible fracture propagation (crack arresters) presents alternative solutions requiring investigation. The implementation of any of the above design decisions requires reliable interpretation of the notch ductility characteristics of the base material.

The Weld Joint Problem

The weld joint problem represents a true weldability problem inasmuch as the properties of the weld joint for the most part are, or should be, under the control of the welding engineer. In a sense the base material picture problem is inherent to the material as purchased. Fundamental data are required concerning a great variety of weld joint problems. Information as to the plastic interaction of weld joints is needed to resolve the question of strength matching of welds and base plate. For example, high strength (overmatching) welds deconcentrate strain when the major stress is transverse to the weld; however, when the major stress is parallel to the weld equal strain will be developed in the weld and plate. Obviously overmatching welds serve no purpose when loaded in parallel with the plate, except possibly to add rigidity. The implications of elastic and plastic interactions of weld joints to welded design should be investigated. This problem is of particular interest to the case of the high-strength welds of the E10016 and E12016 types.

The role of notch toughness in determining the performance of welds requires further study. Tests have indicated that high notch toughness, rather than high strength, is the primary factor which determines the improved performance of E12016 (Grade 260 Mil Spec.) welds for high-tensile structural steels. The level of weld notch toughness required for specific service needs should be established. In general fractures of structural steel weldments do not follow welds; this fact is in agreement with the known higher notch toughness of conventional welds as compared to structural steels. In fact crack stopping by welds has been demonstrated in service and by crack propagation experiments. This suggests that the contribution of welds to failure initiation is inherent to the presence of weld defects and that sound welds do not contribute *per se* to failure. The problem of weld fissures as affected by cooling rates and electrode type requires further investigation in this respect.

The heat-affected zone appears to be the most difficult of all weld joint problems. The effects of welding procedures, type of electrode and base metal characteristics combine to control the final quality of the heat-affected zone (HAZ). Considerable evidence exists that the heat-affected zone generally provides the initial crack fault which then forces the adjoining base metal to perform in the presence of sharp notches. The formation of crack faults in the heat-affected zone may be compared to the machining of notches in the base plate, i.e., it does not then represent fracture initiation of the base plate, but it does represent "notching" of the base plate. The effect of the "notch" is determined by the intrinsic properties of the base material; however, the presence of HAZ cracks is highly demanding of the notch ductility of the base material. Improvements in the HAZ by development of information concerning the proper methods of welding for specific steels requires investigation of basic factors which determine HAZ quality. Also, from a practical shop viewpoint, simple tests to evaluate HAZ quality are needed for piloting the development of welding procedures. The effects of stress, hydrogen, thermal cycle and steel characteristics present combined metallurgical and mechanical properties problems requiring step-by-step investigation of each variable.

Synthesis of Service Conditions

Efforts to develop laboratory tests which synthesize specific conditions of service should be continued. This is a field which requires sound logic and ingenuity and which presents a real challenge to investigators. The rigidity characteristics of complex structures as compared to the relative nonrigid characteristics of conventional test pieces provide one field of investigation. Perhaps rigidity or plasticity factors could be reduced to semiabsolute terms. The crux of the service synthesis problem is one of structural triaxiality (corners, etc.) as compared to defect triaxiality (crack, etc.). The effects of the two may be pyramided in service, i.e., a defect at a position of structural discontinuity perhaps should be considered to be intensified by the factor of structural triaxiality. Size effects may be considered as part of this general problem inasmuch as rigidity is affected thereby.

The residual stress problem is a challenging one which so far has defied conclusive evaluation. The crux of this problem relates to the contribution of residual stresses to the problem of brittle failure. Two divisions of the problem should be recognized: (1) the residual stress pattern (short range) of near weld zones which possibly contributes to fracture initiation and (2) the locked-in stress (long range) problem of the over-all structure which possibly contributes to fracture propagation. Research is required to determine the effects of residual stress systems and of the contribution of various stress-relieving processes to alleviating the problem if such exists. Specialized laboratory tests entailing controlled stress systems are required to resolve the problem. This research presently requires the use of relatively large and complex specimens with consequent slow progress and difficult analysis of results.

Fatigue effects on the performance of welded joints should be investigated under various conditions of rigidity. This problem is particularly significant to the case of welded fabrication of beams by means of cutting and rewelding standard structural shapes. While information is available for the most common rolled structural shapes very little is known concerning the more complex welded shapes. Studies of fatigue in the plastic range (short cycle fatigue) should be extended.

Specific Problems

The foregoing section outlined the generalities of the mechanical properties and testing problem. Specific problems which require investigation are listed below in order to provide a clearer definition of the subdivisions of the broad problems which may be undertaken as specific research projects.

1. Investigate the relation of notch ductility to structural performance. Establish the significance of Charpy V, keyhole and Schnadt type specimens.

2. Determine the conditions for fracture initiation. Express these conditions in terms of plastic deformation at notch tips. Is it necessary to develop a finite amount of deformation at notch tips or is the initiation problem simply one of elastic overstressing?

3. Determine the conditions for fracture propagation. Establish the possibility of representing the "go"-"no go" conditions of fracture propagation in terms of absolute energy levels. Determine if a minimum stress level for fracture propagation exists or if this is merely a temperature-dependent function.

4. Investigate the effects of steelmaking practice variables on the initiation and propagation characteristics of brittle fracture; compare rimmed, semikilled and fully killed types.

5. Establish the importance of strain rate effects particularly with respect to stress or strain relaxation at notch tips.

6. Investigate the possible contribution of strain aging to the brittle fracture problem. Strain-aging effects may be aggravated at plastic hinge positions in structures since near weld regions are conditioned for aging reactions by the weld thermal cycles. Strain aging affects the ductility transition considerably and the fracture transition relatively little; establish the significance of this.

7. Industry encounters difficulty in the welding of low-quality steels containing segregations, laminations and inclusions, particularly with the submerged arc process. Establish the effects of chemical segregation on a near microscopic scale on the properties of weld joints.

8. Investigate the notch ductility transition characteristics of weld deposits. Determine the variables related to welding procedures and base metal dilution aspects which affect weld metal properties. Investigate the influence of electrode coatings, particularly with respect to hydrogen content and, also, the effect of weld restraint on weld properties.

9. Preheat is used to control cooling rates. Additional research is needed to clarify the mechanism by which cooling rate affects the development of weld fissures and the properties of the HAZ.

10. Service records indicate that ship failures occur in greatest frequency during the spring months. Investigate the effects of holding time at low temperatures on the problem of fracture initiation at weld regions. Service records also indicate that welded vehicles which are placed in service during the summer are more resistant to brittle fracture than if placed in service directly in the winter.

11. Welding at low temperatures is known to be hazardous to service performance. Investigate the effects of welding cold metal.

12. Investigate the limits to which the use of low-hydrogen electrodes may be used effectively in lieu of preheat in welding structural steels.

13. Investigate the effectiveness of thermal stress-relieving treatments in preventing brittle fractures. Compare furnace stress-relieving effects with low-temperature stress-relieving effects.

14. The use of high-strength weld metal which overmatches the strength of the base metal is considered to result in forcing yielding to other regions and accordingly to protect the structure from the action of weld defects. Consider the possibility of enhancing the action of HAZ defects and otherwise aggravating the HAZ problem. Would it be better to aim for a matching of strength properties and to protect the structure from the action of weld defects by increasing weld notch toughness?

15. Investigate the relative significance of free moisture and water of recrystallization present in electrode coatings. Consider the effectiveness of 300° F baking of moisture-damaged electrodes.

16. The subject of peening last passes of welds is highly controversial. Investigate weld metal properties and weld joint behavior in this respect.

17. Minute defects, such as arc strikes, have been determined to cause structural failures. The critical nature of such defects apparently is due to the associated sharp cracks. Investigate the general problem of accidental defects and the effects on the performance of the base material.

18. Investigate the significance of "metallurgical notches," i.e., conditions created by the close association of materials of various strength and ductility characteristics. Determine the relative contributions of strain concentration and of rigidity as factors which determine the effects of metallurgical notches.

19. Investigate the application of sonic methods to the nondestructive testing of weldments.

20. Develop simple and reliable methods for the nondestructive testing of flash and spot welds.

21. Determine the magnitude and distribution of stresses in welded joints, particularly for pipe.

22. Investigate the effects of plastic straining, such as developed during hydrostatic pressure tests on the properties of weld joints.

IV. STRUCTURAL AND DESIGN

Projects Requiring Limited Financial Support

(A) Studies and Experimental Work Related to Fatigue Resistance, But Not Requiring Fatigue Testing Machines

In view of the fact that structural fatigue testing work must be carried out on fairly large testing machines, using rather large specimens to get significant results, the following suggestions are limited to work of a pilot test nature to determine stress distribution. It is the thought that such studies would narrow the range that would have to be covered by physical testing of actual welded steel specimens subjected to cyclic loading. These pilot tests might be carried out by polarized light studies, or on welded steel specimens with brittle lacquer coating, if it is found that sufficiently accurate determinations could be made by the latter technique.

1. Shape of end of a reinforcing cover plate, or the end of a fillet-welded strap that is used in a lap joint: We have found that tapering cover plates virtually to a point does not provide as good fatigue resistance as an end that is simply cut across normal to the length of the plate or strap, provided that suitable sizes of end fillet welds are used. In Europe, some advantage seems to be attributed to the rounding of the corners of the end of such a plate. It is somewhat expensive to make the rounded corners. Perhaps the same thing could be accomplished by clipping them on a 45-deg diagonal line, but still leaving a substantial part of the original square end.

2. Omitting longitudinal fillet welds near the end of a fillet-welded plate such as a cover plate or strap: Fatigue tests have shown that the resistance of specimens with such square end cover plates or straps is just about as good with the transverse fillet welds alone, as when a longitudinal fillet weld is added along each edge adjacent to the end transverse weld, provided the end transverse weld is of suitable size. However, under practical circumstances, such longitudinal fillet welds are required. It has been proposed to investigate the omitting of the longitudinal fillet welds for a short distance at the end of such a plate, adjacent to the transverse weld.

3. Balanced design for size of fillet weld as compared with thickness of material: In fatigue tests at the University of Illinois, it was found that specimens that were proportioned for balanced design in accordance with the generally accepted allowable unit stresses for welds and plate material, under static loading, did not prove to be a balanced design in the case of fatigue loading. However, the information developed thus far is not sufficient for setting up practical rules for proportioning fillet welds for balanced design. In fact, such a balanced design might not be desirable, if it resulted in an over-all loss of joint efficiency. This might be studied on comparatively small specimens.

4. Model testing to determine how fillet-welded joints should be designed to avoid secondary bending stress in so far as possible: It is possible that some of the inconsistencies that seem to have appeared in the results of fatigue tests, can be explained on the basis of secondary bending stresses, whereas in conventional design, only the nominal stress is computed.

5. Investigation of the comparative severity of the notch effects at the toe and root of a fillet weld: It has been proposed to increase the efficiency of a fillet-welded lap joint by some kind of special treatment, either by grinding or, perhaps, by flame hardening applied at the toe of the fillet weld. This would pertain also to the transverse fillet across the end of a welded cover plate of a girder. The question to be decided is whether this would still leave a sufficiently severe stress raiser at the root of the fillet weld, that failure would simply shift from the toe to the root, without a very substantial increase in fatigue resistance.

6. Determination of the suitable angle of tapering

the thickness of a thicker plate that is joined to a thinner one by means of butt welding: Various design specifications specify this tapering thickness to have a slope ranging from 5:1 to 2½:1. It would be desirable to determine the maximum slope that is permissible without sacrificing a substantial amount of fatigue resistance. It is more expensive to make the flatter slope in such a transition from a thick member to a thin member.

7. Optimum proportion between length of longitudinal fillet welds and transverse fillet weld in a group of fillet welds at the end of a bar, or strap, forming part of a lap joint: In the work that has been done to date, we have found that this ratio has an important bearing upon fatigue resistance, but we do not have a sufficient amount of specific data as to the optimum ratio.

8. Effect of length of any attachment to a main element of a member: This is a general matter which has one specific example in the case of the matter of whether or not one should permit the welding of bearing stiffeners to the tension flange of girders, at points of high stress. We are led to believe that when an attachment, such as a gusset plate or a lateral connection plate, extends over a considerable length of a tension element or tension member, it is long enough to pick up main stress and share in the stress. This results in a considerable degree of stress concentration at each end of the attachment. On the other hand, the attachment of something like a bearing stiffener is so short in the direction of the length of the main member that it does not pick up very much stress and, in that way, share in the main stress of the main element or member. Therefore, it appears that there would be less of a concentration of stress and less adverse influence upon fatigue resistance.

(B) Studies and Experimental Work of a General Structural Nature

1. An intensive practical study, which would be carried out in the department of shop practice of a university, to determine the best kind of a backing to provide at a butt-welded joint that is accessible from one side only: The usual method of doing this is to provide a narrow backing strip that is fused by the weld metal and is not subsequently removed (because it is not accessible or for other reasons). With low-hydrogen electrodes, particularly, it is rather difficult to get the weld started properly without any porosity, at such a backing strip. Also, in welding with any kind of electrode, one must be rather careful with his technique and procedure, in order to assure sound welding. By a systematic program of trial and error, it might be possible to develop the best procedure and technique as well as the best method of preparation for such welding. One possibility is to deposit a bead, or several beads, along the bottom edge of the end-face of each member to be joined, in advance of the fitting of the two butting parts to be welded. It is quite largely a matter of whether such a technique or arrangement, or, perhaps, the making of a U-shaped groove, will provide just as sound a joint as one that is executed on a backing strip with wider root spacing. This problem should be investigated with the use of low-hydrogen electrodes, and, also, with the use of conventional electrodes such as AWS Class E6010.

2. Attempt to develop a type of crack-arrester that could be used in lieu of a riveted crack arrester, so that the punching of holes and driving of rivets would be avoided in a structure that is otherwise all welded: This might be accomplished by introducing metal of exceptionally high notch toughness, in the form of a plate, or possibly in the form of weld metal. We have some evidence from the program at Columbia University that weld metal deposited by low-hydrogen type electrodes does resist the propagation of fracture much better than ordinary weld metal. Similar information has been developed from small-scale tests, but it has never been applied with the idea of providing a crack stopper or arrester.

3. Effect of overmatching or undermatching the base metal with weld metal of higher yield point, or weld metal of lower yield point: This has long been a controversial question in connection with resistance to brittle fracture as well as resistance to fatigue.

4. Proportioning of new types of rolled steel sections that are especially adapted to welded construction: This is something that has been talked about for many years but no one has ever come up with a really good comprehensive discussion, based upon practicability of producing such sections, the extent of the demand for them in the event that they were available, etc.

5. Influence of degree of temperature, size of heated areas or spots, as used in the flame-shrinking process to remove buckles from plating: It is thought that general practice has involved higher temperatures of heating and larger spots than are needed, but no carefully controlled tests have been made to determine whether this is true or not.

6. Development of the most practical and effective method of butt welding two pieces of steel reinforcing bar material together, for use in reinforced concrete construction.

V. RESISTANCE WELDING

Resistance welding embraces the processes of spot welding, seam, projection, flash, upset and percussive welding. A detailed description of each of these processes, and the equipment necessary thereto, is contained in the WELDING HANDBOOK published by the AMERICAN WELDING SOCIETY.

The research problems are rather arbitrarily divided into: (*A*) Electrical and Physical Characteristics, (*B*) Metallurgical Effects and (*C*) Physical Properties and Tests. However, there is considerable overlapping among these groups.

(A) *Electrical and Physical Characteristics*

1. Determine the relationship between electrical contact resistance and the current, pressure, temperature and surface preparation of the metal welded. An additional phase of this problem involves the thermal contact resistance and the same variables. Another problem would be to investigate the possibility of the application of spreading resistance techniques to spot welding of copper.

Researchers are referred to technical reports published by Rensselaer Polytechnic Institute and Johns Hopkins University on this subject.

2. An investigation of electrical-resistance brazing including current density, pressure, temperature and heating time for specific brazed areas, comparing results with conventional furnace heating. Some limitations are encountered in making large area joints by furnace brazing, and this tendency should be studied in resistance brazing.

3. Study the effect of postheating on the fatigue strength of spot welds. Postheating is one method that holds possibility of increasing the comparatively low fatigue strength of spot-welded joints.

4. A study of projection welding of low-carbon steel involving smaller-sized welds than those in present recommended practices. These data would be useful in applications where welding must be accomplished in restricted areas.

5. A study of spot welding and projection welding of aluminum involving smaller-sized welds than those in present recommended practices. This investigation would indicate procedures in cases where edge distances must be kept at a minimum.

6. The production of series and multiple spot welds in aluminum alloys.

7. The application of slope control to minimize edge distance in the spot welding of stainless steels and other alloys.

8. Investigation of new techniques providing rapid follow-up with low electrode force. This investigation should prove helpful in cross-wire welding and projection welding of soft materials in small section sizes.

(B) *Metallurgical Effects*

1. Investigate the metallurgical effects of welding dissimilar metals. Work with Monel, nickel, Inconel and chrome nickel stainless grades should be considered.

2. Spot welding of copper: This process depends on proper electrodes which will not deteriorate in contact with the copper workpieces. It may be necessary to generate additional heat within the electrodes so that the fusion temperature may be reached in spite of the high thermal conductivity of the copper workpiece.

3. Spot welding of silicon bronze, silicon brass and red and yellow brass to determine optimum welding conditions: Contact resistance must be carefully measured and the application of electron diffraction equipment might be useful to study the surface films on these alloys.

4. A study of the effect of welding conditions upon the mechanical properties and corrosion resistance of spot-welded aluminum alloys.

5. Investigation of the effects of spot welding on steels coated with low melting point metal, e.g., galvanized steel, tin plate, terne plate, gilding metal.

6. Effect of metallurgical quality (deoxidation, grain size, surface finish) on the spot weldability of steel: In this case, surface contact resistance is of prime importance.

7. Micro investigation of the fusion line of flash and upset butt-welded joints for decarburization, or other variations in structure produced by variations in the welding conditions: Anomalies in properties of these welded joints have been ascribed to local variations in the structure at the fusion line.

8. Cross-wire welding of very fine (0.001- to 0.002-in.) tungsten, molybdenum and other nonferrous wires to larger diameter wires (0.015 to 0.020 in.) of nickel or nickel-plated steel.

9. The flash welding of heat-resistant stainless steels in gages under $^1/_8$ in.

10. Study of the spot welding of aluminum, involving single-phase, up and down slope control and forging pressure.

(C) *Physical Properties and Tests*

1. Spot welding: Evaluation of the effects of residual stress in spot-welded assemblies. Stress concentrations of a severe order exist in spot welds and have an influence on the properties.

2. Development of nondestructive tests and evaluation methods for resistance welds.

3. Effect of fiber distortion in flash and upset butt welding: A study could include a cold-rolled or drawn material with pronounced longitudinally oriented structures plus the same material in the normalized condition.

4. The study of multiple spot welds: This investigation should determine the stress distribution in specimens with multiple spot welding.

Considerations of Welded Hatch Corner Design

This report has been prepared and published by the Ship Structure Committee in accordance with the duties and responsibilities vested in the Committee by the Secretary of the Treasury, United States of America

Forword

1. The large number of welded ship failures early in World War II focused attention upon the destructive potential of structural notches. Complete elimination of notches from a ship is impossible. However, elimination of the destructive effects originating at structural notches is generally possible through design. This has been demonstrated by successive stages of development of satisfactory all-welded hatch corners.

2. The original hatch corner of the Liberty vessel proved to be one of the worst crack initiators. As a result this hatch corner was modified and those of later Liberties were redesigned.

In the Victory class of vessels, and other vessels subsequently constructed, additional design improvements were incorporated into the hatch corner.

3. Because of the importance of the problem, complete service and fracture records have been analyzed and full-scale laboratory tests of hatch corners, duplicating as closely as possible construction and service conditions, were performed. Results of these tests have been analyzed for correlation with actual service performance.

4. In view of the significant volume of accumulated service data and associated laboratory test data available, the Ship Structure Committee has undertaken to evaluate and interpret these data in terms of design features intended to produce crack-resistant hatch corners in welded steel vessels. The results of such undertaking are contained in this report.

We urge that this material be used in the development of new hatch corner designs.

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THE purpose of this report is to assemble and summarize such portions of the available information relating to hatch corner failures and tests as are significant in the actual design of a welded hatch corner for a typical cargo vessel. Attention will be paid principally to the matter of the geometry and size of the structure. For this reason such factors as temperature, notch sensitivity of the material, and strain rate, which are known to be contributory causes of failures are not discussed. The hatch corners particularly referred to in the report are those on the weather deck of a cargo vessel and located in the mid-ship 3/5 length. The design principles given here apply also to corners located elsewhere but to a lesser degree. It is not to be considered that this report presents the final word with reference to hatch corner design. It represents merely the best advice that can be given at the present time, based on the available Ship Structure Committee data on this subject.

1. GENERAL CONSIDERATIONS

(*A*) *Homogeneous Structure Concept*

The ultimate objective of structural design is to obtain, if possible, a homogeneous structure. That is, at all loads up to failure, component parts of the structure behave in a parallel manner with regard to stress and elongation. It is only in this way that an approach to the full strength characteristics of the material can be realized. These general statements are particularly true with respect to hatch corners. Let us suppose that a hatch corner exhibits high ultimate nominal stress but low energy absorption. This means that its total elongation to rupture is low. The resisting stresses in other parts of the structure are a function of the load-elongation properties of the material. Since all components must elongate together, the hatch corner in question possesses the characteristic of accumulating higher stress in proportion to its elongation than do adjacent components, and therefore will be subject to early destruction because it will attract more than its fair share of the load to be resisted.[1] Conversely, a hatch corner that exhibits low ultimate nominal stress but high energy absorbing ability, through high elongation properties, would shirk its share of the applied loads.

Thus it appears that neither the ultimate failure load of a hatch corner, nor its energy-absorbing qualities

may be considered singly as a suitable criterion for hatch corner design. Ideally, both these qualities of a hatch corner should be considered in association with similar characteristics for the surrounding structure. From a practical design standpoint this approach to the problem leads to no solution for several reasons, among them the fact that no simple analytical means is available for determining the load-strain relationship for a particular hatch corner design. Hatch corner design must, therefore, be a process involving the intelligent use of good basic practice coupled with constant reference to successful previous designs.

(*B*) *Geometrical Arrangement*

There is a large number of possible geometrical arrangements for the design of a hatch corner. In the choice of the geometry to be used, attention must be given to two factors: (*a*) Structural Adequacy, and (*b*) Method of Fabrication. In structural design, neither of these factors can be ignored, and a suitable compromise must be adopted. From past experience with welded hatch corners, it is clearly evident that in the conflict between these two factors the structural adequacy of the corner must be considered first. The original corner used in Liberty vessels, Fig. 1, was an example of overemphasis on ease of fabrication, while the Kennedy-type corner, Fig. 2, probably exemplifies the opposite approach.

In the choice of the geometry to be used, primary consideration should be given to the location and severity of the unavoidable notches. A notch may be defined as any discontinuity. Notches vary in size from small imperfections in the weld up to the hatch corner which is itself a large notch. The serious effect of notches is twofold, involving first the stress magnification which always exists and, second, the fact that the material is under considerable constraint which prevents normal yielding, and causes the material to react in a brittle manner. In addition, the possibility of compounding notches should be avoided. By compounding is meant the location at the same point of separate notches in two members of the structure or the creation of a notch within a notch such as the formation of a weld cavity in a region of multiaxial stress.

(*C*) *Thickness of Plating*

It is always desirable in structural design to limit plate thickness to the minimum acceptable value in order to obtain an economical structure. In the case of relatively large structures containing stress concentrations (such as hatch corners), it has been found that a fairly definite relation exists between the thickness of steel plate and its notch sensitivity. The heavier gages of ship plate are usually more notch sensitive than lighter plates of the same class of steel. For these reasons it is important that plate thickness be limited to the minimum acceptable values.

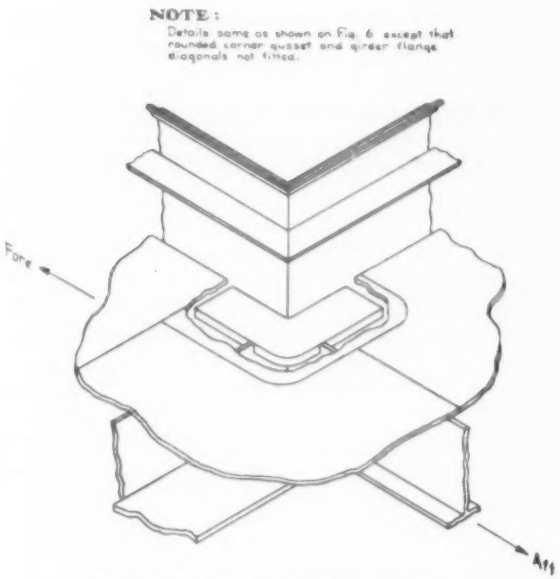


Fig. 1 Liberty ship square hatch corner

(*D*) *Location of Stanchions*

By far the largest number of cargo vessels constructed in recent years have been fitted with centerline stanchions. This arrangement is preferred by some operators in the belief that for certain trades the centerline location causes less interference with the loading of cargo into 'tween decks and holds than the arrangement with corner stanchions. Thus the greater part of service experience data which are available apply to the centerline stanchion arrangement. A lesser number of cargo vessels, however, have been constructed with stanchions located under the hatch corner. There is no factual evidence to indicate any superiority of one arrangement over the other, in so far as the performance of the hatch corner is concerned.

(*E*) *Deck Corner Reinforcement*

It has been common practice in shipbuilding to reinforce the corners of the deck openings where stress concentrations were known to occur. The recent experience with the Liberty vessels as well as the hatch corner test program has afforded an opportunity to study the effect of such corner reinforcement. It has been found that corner reinforcement improved the nominal stress at failure of the laboratory test specimens and reduced the incidence of fracture in vessels under service conditions.[2]

It is therefore considered desirable to reinforce the deck corner by the use of heavier deck plating or by the addition of doublers. The area of increased thickness should be of relatively large size and carried well around the corners of the opening. There is little factual information to indicate the optimum amount of extra thickness. Since the use of doublers for corner reinforcement

increases the amount of welding necessary in the corner area, insert plates are considered preferable.

II. HATCH CORNER DETAILS AND TESTS

The full-scale hatch corner tests, as conducted under the direction of the Ship Structure Committee, and the performance of the Liberty and Victory vessels in operation, offer the best means available for making a study of various designs of hatch corners. Figures 1, 2 and 3 show the three most important types of hatch corner design which have been included in the series

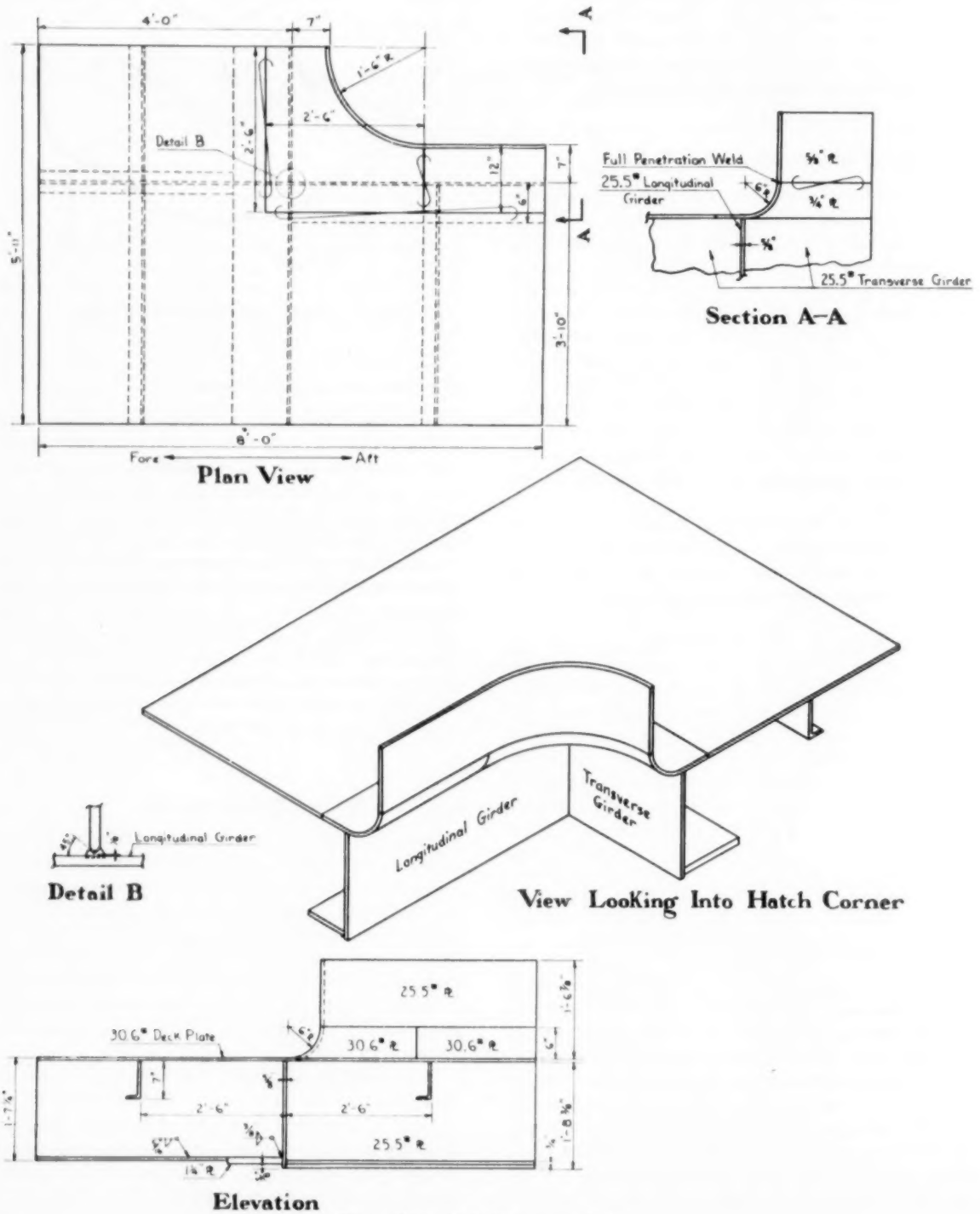


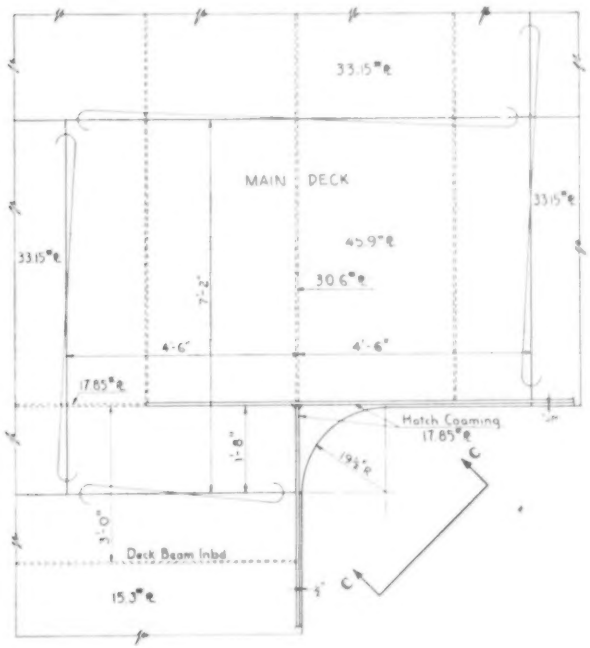
Fig. 2 Kennedy hatch corner design

tested. Taken as a whole the tests show the efficacy of various attempts to alleviate the critical condition found to exist in the original Liberty ship hatch corner design.

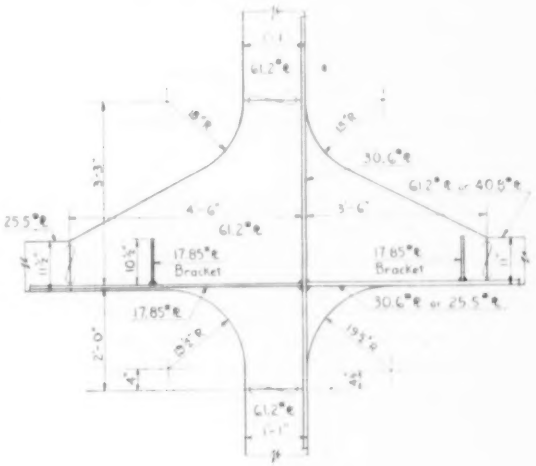
(*A*) *Liberty and Victory Types*

The original hatch corner, Fig. 1, represented a compounding of severe notches resulting in triaxial stress conditions which restrict natural plastic flow and cause the material to act in a brittle manner. Four severe notches are concentrated around the point of intersection of the deck, longitudinal girder and hatch end beam. These four notches are shown schematically in Fig. 4. The details of the design prevented complete penetration of the welds at the corner. The resulting cavities constituted notches within the four notches illustrated in Fig. 4. These additional notches are not readily illustrated.

An informative comparison can be made between this original hatch corner and the successful corner, Fig. 3, employed in the construction of the Victory vessel. The manner in which the difficulties encountered in the Liberty design were avoided, or minimized,



Section A–A



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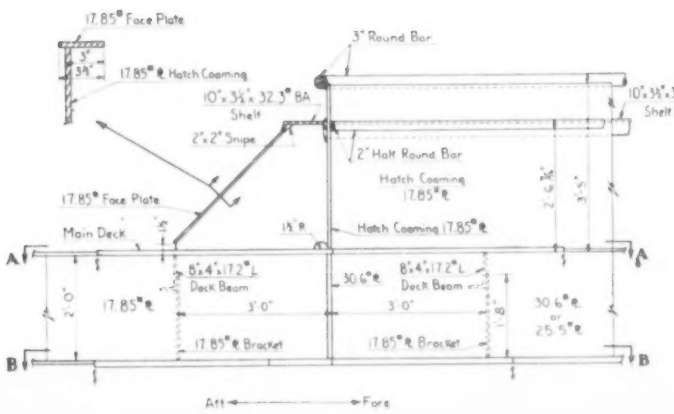

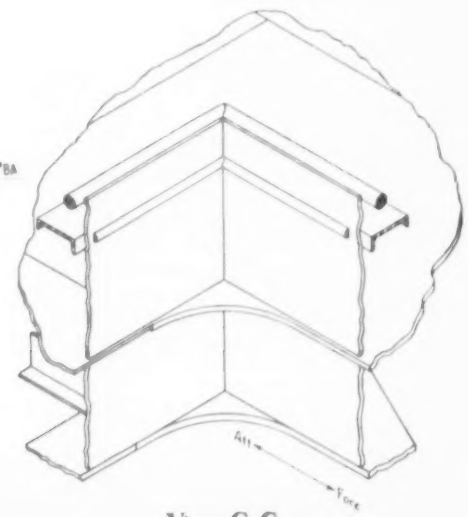

View C–C

Fig. 3 Victory ship hatch corner

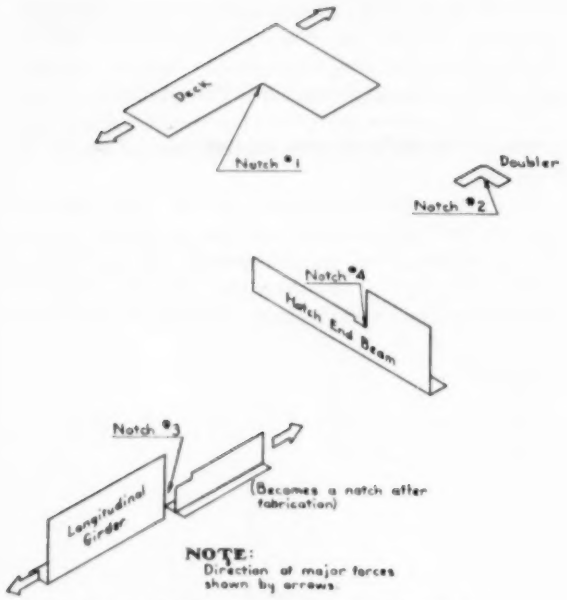

Fig. 4 Liberty type members (schematic)

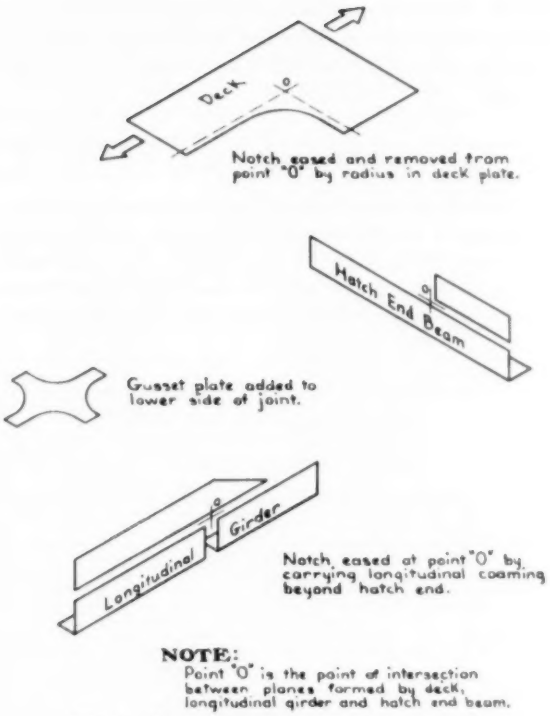
Deck
Notch eased and removed from point "0" by radius in deck plate.
Hatch End Beam
Gusset plate added to lower side of joint.
Longitudinal Girder
Notch eased at point "0" by carrying longitudinal coaming beyond hatch end.
NOTE:
Point "0" is the point of intersection between planes formed by deck, longitudinal girder and hatch end beam.

Fig. 5 Victory type members (schematic)

in this design will be apparent from Fig. 5 and the following discussion.

The improvements consist in easing the notches in tensile members (deck and longitudinal girder) and in moving the remnants of these stress concentrators to new and separate locations. Added continuity of structure and improved local welding conditions were provided by the addition of a radiused gusset plate at the level of the flange of the girders below deck.

Figures 6 and 7 illustrate two of the modifications applied to the original Liberty ship hatch corner design. These modifications have been included in the test series.

Figures 6, 7 and 3, are not considered to represent optimum hatch corner designs but rather successive

TABLE 1

RESULTS OF LABORATORY TESTS AND ANALYSIS OF SHIP SERVICE RECORDS (APPROXIMATELY TO END OF 1950) OF VARIOUS HATCH CORNER DESIGNS

Figure Number	Type	Record of Structural Performance in Service			Data from Laboratory Tests (*)	
		Ship Years in Service	Fractures Reported at Hatch Corners	Hatch Corner Fractures per 100 Ship-Years	Energy Absorpt. at Failure Inch-Pounds	Nominal Stress at Failure Pounds/Sq. In.
Figure 1	Liberty Ship with Square Hatch Corner	2,110	224	10.60	230,000	24,000
Figure 6	Liberty Ship as altered with rounded bracket	4,400	31	0.70	921,000	31,450
Figure 7	Liberty Ship with rounded Deck Plate and Doubler	3,750	1	0.03	3,627,000	35,500
Figure 3	Victory Type	2,100	0	0.00	5,800,000	33,200
Figure 2	Kennedy Type	—	—	—	6,786,000	54,100(**)

(*) Laboratory specimens varied somewhat from the actual ship detail to permit practical fabrication and testing procedure.

(**) Failure started from a notch resulting from an arc struck inadvertantly where no weld was intended.

stages of design improvement which still include some undesirable notches.

(B) *Kennedy Type*

The Kennedy hatch corner shown in Fig. 2 represents the design which gave the best performance under laboratory test conditions. This corner showed superiority in ultimate unit stress as well as energy absorption over other types of hatch corner specimens tested. Due to the difficulty of establishing the effective area of metal in tension, the test results are not directly comparable with those of other types.

Since the design requires rolled coamings, with hot-formed corner pieces, it is more difficult to repair or renew than other types.

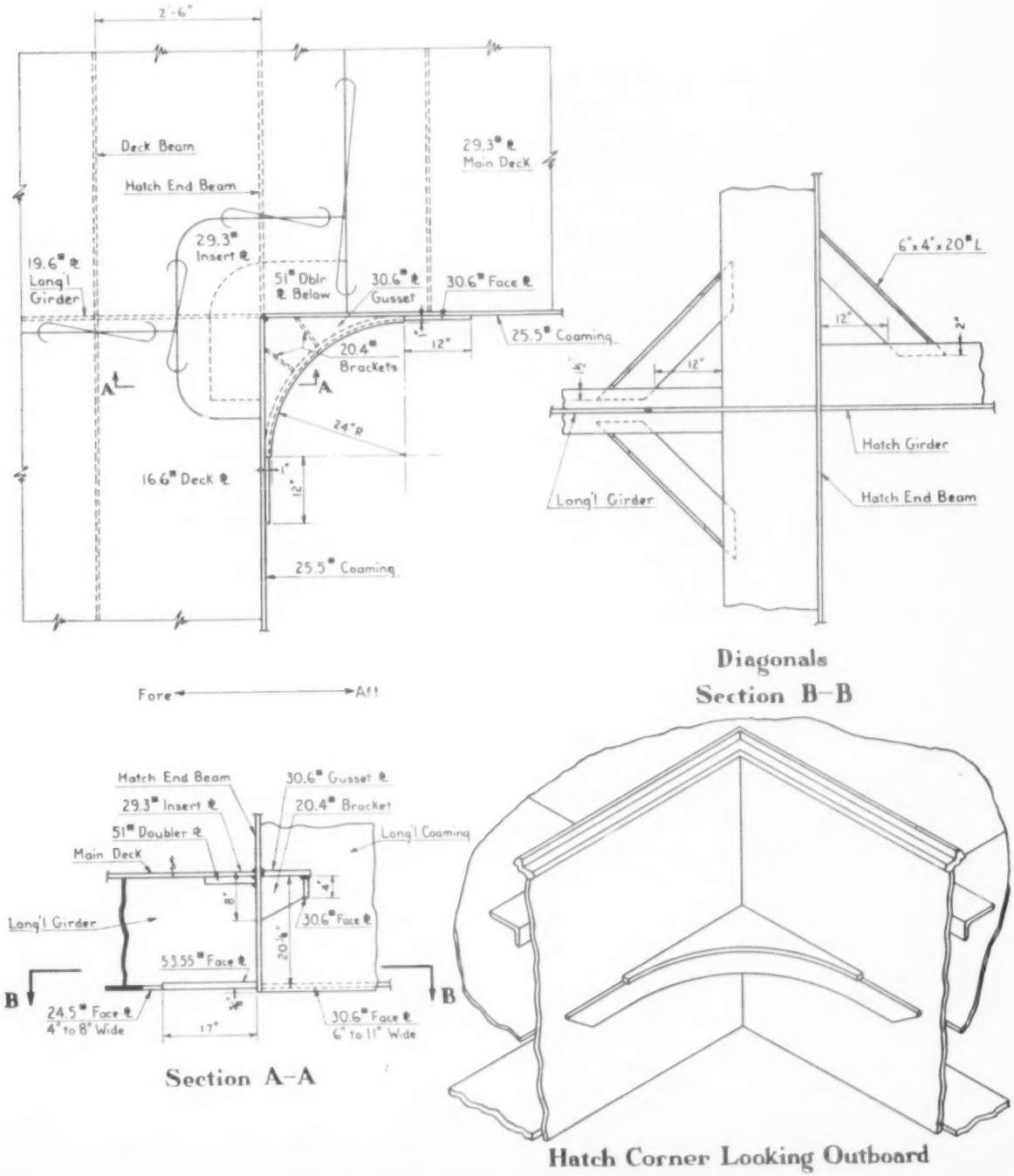

Fig. 6 Liberty ship hatch corner with rounded bracket

(C) *Rounded-Coaming Type*

From an arrangement standpoint, the Victory corner has a disadvantage in the fact that the hatch-side coaming extends one frame space beyond the end of the hatch. This might be an awkward arrangement, limiting access around the end of the hatch, and possibly influencing winch locations and other fittings in that area.

As an alternative to the Victory corner, the rounded-coaming hatch corner shown in Fig. 8 has been used successfully on a number of vessels of the C3 type since 1947. It was designed to eliminate the right-angled coaming intersection at the corner with the intent that the longitudinal coaming stresses taper gradually down into the deck and girder. Rectangular hatch covers may be used by squaring the corner at the level of the top of the coaming. No laboratory tests of the design have been made, nor has any investigation been made of the service extremes to which these vessels have been subjected.

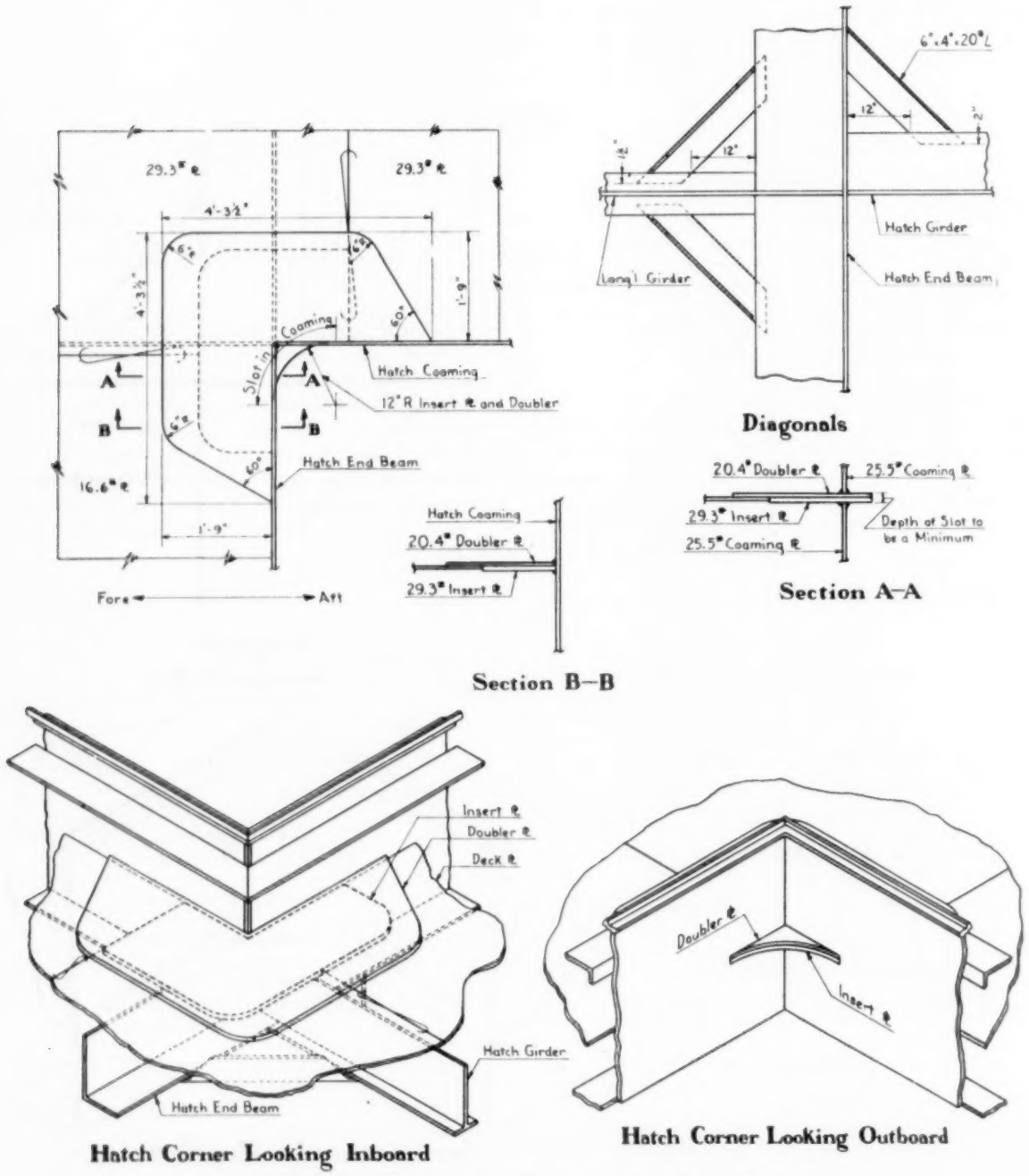

Fig. 7 Liberty ship hatch corner with rounded deck plate and doubler

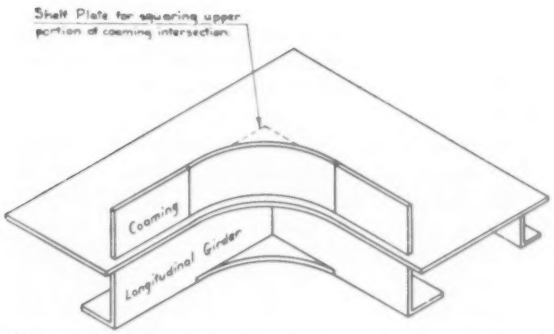

Fig. 8 Round coaming hatch corner design (simplified sketch)

(D) *Hatch Corner Test Data and Service Records*

The results of laboratory tests[3] and an analysis of the service records[2] of the various types of hatch corners described previously are contained in Table 1. It is important to note that the material, welding influences and test temperatures for the laboratory test specimens were the same. As a result, the test data demonstrate the very considerable benefits that can accrue from careful attention to design. That the test data correctly reflect the performance of the hatch corners in service is shown by the fracture record contained in Table 1.

III. HATCH CORNER DESIGN PRINCIPLES

It is evident from the foregoing discussion that, among the many contributory causes for failures of hatch corners, one of the most significant factors is the choice of the geometrical arrangement. In order to emphasize the important basic points to be considered in hatch corner design, they are summarized and restated as hatch corner design principles.

(A) *General Principles*

1. Ease notches in all members and especially those carrying main longitudinal stresses.
2. Avoid coincidences of notches.
3. Avoid the intersection of welded joints as far as possible, especially at points of stress concentration.
4. Minimize welding defects by proper design for welding.

(B) *Specific Suggestions*

Selection of specific suggestions listed below must depend upon the ship design. Effective hatch corner reinforcement need not incorporate all of the features listed below. The judgment of the designer must prevail.

1. At the corner provide a heavier deck plate with a generous radius. (For main hatches in typical cargo ships such as the Liberty, a radius equaling one-twentieth of the transverse dimension of the opening was satisfactory.)
2. Taper hatch side coaming beyond hatch end.
3. Ease longitudinal girder to hatch end beam connection at flange level as by radiused gusset.
4. Specify full penetration welds for joining deck to coaming in way of the hatch corner and for such joints as are subject to direct loading, in order to avoid cavities or piping in such welds, especially those perpendicular to the principal tensile stresses.

References

1. MacCutcheon, E. M., Discussion of paper "Tests of Various Designs of Welded Hatch Corners for Ships," by E. P. DeGarmo, THE WELDING JOURNAL, **27** (2), Research Suppl., 69-s to 70-s (1948).
2. Technical Progress Report (First) of the Ship Structure Committee, Mar. 1, 1948.
3. DeGarmo, E. P., and Boodberg, A., "Causes of Cleavage Fracture in Ship Plate; Hatch Corner Design Tests," Ship Structure Committee Report Serial No. SSC-16, Dec. 4, 1947.
4. "The Design and Methods of Construction of Welded Steel Merchant Vessels," Report of an Investigation, Government Printing Office, 1947

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IIW "Collection of Reference Radiographs of Welds"

At the yearly meeting of the International Institute of Welding in Gothenburg 1952, the Commission V for Testing and Measurement appointed a subcommission to undertake the task of preparing a "Collection of Reference Radiographs of Welds," showing typical welding defects and different degrees of defect severity (weld degree).

The collection is intended as a guide for interpretation of radiographs, putting the different countries on the same footing, and is considered to be a valuable tool for educational purposes such as training of welders, instruction of radiologists, inspectors, etc.

An issue of the collection is now available. It is submitted by a central office created by the national organizations for nondestructive testing in Denmark by Svejsecentralen, Holland by Röntgen Technische Dienst, Norway by Röntgenkontrollen and Sweden by Tekniska Röntgencentralen. The collection consists of 50 radiographs of arc welds in steel plates with thicknesses from 10 to 30 mm. The different welding defects are divided into 6 groups, according to earlier decision of IIW Comm. 5, as follows:

(*A*) Gas bubbles
Aa: Porosity
Ab: Piping

(*B*) Slag inclusions
Ba: Inclusions of any shape and any direction
Bb: Slag lines
Bc: Weaving faults
Bd: Faults from bad chipping
Be: Faults from electrode change
Bf: Faults from junction of seams

(*C*) Lack of fusion

(*D*) Incomplete penetration

(*E*) Cracks
Ea: Longitudinal cracks
Eb: Transversal cracks

(*F*) Undercutting

The severity of the welding defects is estimated in 5 deg indicated by the colors black, blue, green, orange and red. *Black* signifies a sound weld and *red* a very bad weld.

The collection is built up into a card system. Every radiograph is framed in cardboard and all specifications concerning the weld as well as the radiographic technique are indicated by punchholes around the frame. This makes it possible within a few seconds to pick out, e.g., all cards giving the defect "porosity," and out of all these cards with the degree blue, etc., in all combinations desired. In addition to the specification concerning welding defects and weld degree, every radiograph is also classified according to the welding position, weld types, intensifying screens and X-ray tube tension. The English text is applied on one side of the frame and the French text on the other side.

Ringbinder with paper copies and box for radiographs on duplicate film

The collection is available either with normal transparent film copies or with paper copies. While the film copies give exactly the same definition and contrasts as the original radiographs, both definition and contrast of the paper copies are slightly inferior to the original radiographs. On the other hand the paper copies do not need a viewing box, but can be examined in normal reflecting light. The film type is recommended for all normal interpretation of radiographs, while the paper type preferably could be used for educational purposes of welders, etc.

All radiographs in this collection have been accepted by the International Institute of Welding, TC 5 for Testing and Measurement. This means that they have been carefully examined by specialists in the 19 countries being members of IIW TC 5.

The issued collection is considered to be the first step toward a complete reference collection. It is the intention to extend the collection as further suitable radiographs are accepted, and to replace any film of the collection when better films for illustrating the particular feature become available.

The selling prices for the first collection, including the 50 radiographs, accepted by TC 5 in 1952, are as follows: (*A*) Copies on duplicate films: 200 Sw. Cr. (*B*) Copies on paper: 150 Sw. Cr.

Copies may be ordered directly from Tekniska Röntgencentralen, Experimental fältet, Stockholm, Sweden, which is acting as Central Office for this purpose.

Statistical Analysis of Behavior in the Transition Temperature Zone

A detailed analysis of the behavior of the keyhole Charpy specimens in the ductility transition zone

by R. W. Vanderbeck, H. D. Wilde, R. W. Lindsay and C. Daniel

INTRODUCTION

NUMEROUS investigations have been conducted to determine the notch toughness of steel at various temperatures, using the standard keyhole-notched Charpy specimen. When the steels have contained less than approximately 0.30% carbon, a considerable amount of scatter in Charpy impact values (foot-pounds of energy) has invariably occurred over a certain temperature range, as exemplified in Fig. 1. Above this range the energy values are all uniformly high, portraying tough behavior, while below it they are uniformly low, portraying brittle behavior. The range in which the scattering of energy values takes place is called the transition temperature range and represents the transition from tough to brittle behavior (the ductility transition).[1] Some temperature within this range is selected as the transition temperature.

Transition temperatures are used extensively in evaluating the toughness of steels since such temperatures are believed to indicate the relative suitability of steels for certain types of service in which brittle behavior at some critical temperature is a possibility.

Considerable interest has been shown in this transition-temperature phenomenon; because of this interest and because of the importance attached to transition-temperature measurements, a detailed analysis has been made in this paper of the behavior of keyhole Charpy specimens in the ductility transition zone. Because of the nature of behavior in the transition zone, it was necessary to use various statistical procedures to evaluate the data. These procedures are briefly described in the text. Since it is also important to determine differences in the behavior of steels in the transition zone, statistical methods are described for this purpose as well.

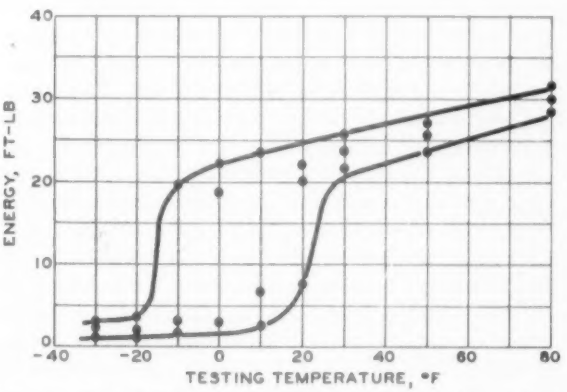

Fig. 1 Typical Charpy impact data using keyhole-notched specimens

The methods of analysis used should be applicable to the transition-zone data obtained when using other types of specimens and possibly other testing techniques, so long as the steel exhibits the same type of behavior in the scatter zone.

BEHAVIOR IN THE TRANSITION ZONE

In the transition zone, it has been noted that the keyhole Charpy energy values are usually either relatively high or very low, with few intermediate values being obtained, as in Fig. 1. In a previous paper,[1] the pattern of behavior shown in Fig. 1 has been described, and a frequency distribution plot has been presented, for more extensive data, showing the number of impact values occurring at each energy level. This plot is reproduced in Fig. 2. The curve shows that the fewest number of energy values occurs at about 16 ft-lb for this particular type of steel, indicating that the energy is changing most rapidly with respect to temperature at this level.

R. W. Vanderbeck is Research Associate with the U. S. Steel Corp., Pittsburgh, Pa.; **H. D. Wilde**, at the time this work was done, was a Research Metallurgist and **R. W. Lindsay** is Associate Professor of Metallurgy with the School of Mineral Industries, Pennsylvania State College, State College, Pa.; **C. Daniel** is a Consulting Statistician, New York, N. Y.

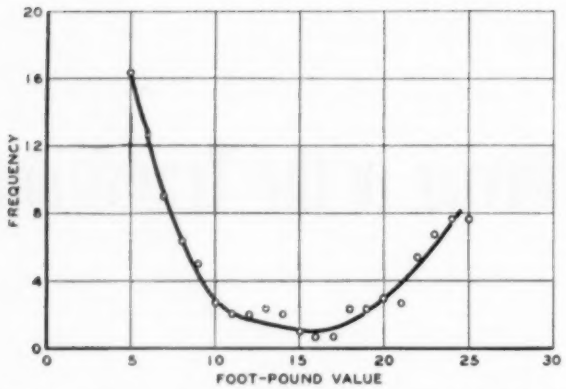

Fig. 2 Frequency distribution of Charpy foot-pound values at all testing temperatures for several steels of one type

The type of energy-temperature curve that would produce this sort of behavior is drawn in Fig. 3. If one specimen could be tested repeatedly at different temperatures, it is hypothesized that the sort of behavior depicted would take place. The same specimen cannot be repeatedly tested, however, and because of the differences among specimens, whatever they may be, the characteristic scatter band is obtained when a number of tests are conducted within the transition zone. Each specimen may be pictured as having a transition curve of its own which could be determined if repeated tests on that specimen were possible. The transition curves of a group of these specimens would appear as the curves in Fig. 4. Only one test, however, may be performed at some temperature on each one of these curves. Since the curve for a particular test specimen is never known in advance, it is obvious that, upon testing within the transition zone, it is much more likely that the test value would fall upon the approximately horizontal branches of these curves than upon the steeply sloping part. Thus, few intermediate energy values would be obtained. It should be pointed out that this postulated type of behavior is not a prerequisite assumption for the statistical methods that will be employed. These methods would also be applicable even if the transition from tough to brittle behavior were discontinuous. (In fact, the methods are better suited for analyzing such behavior.)

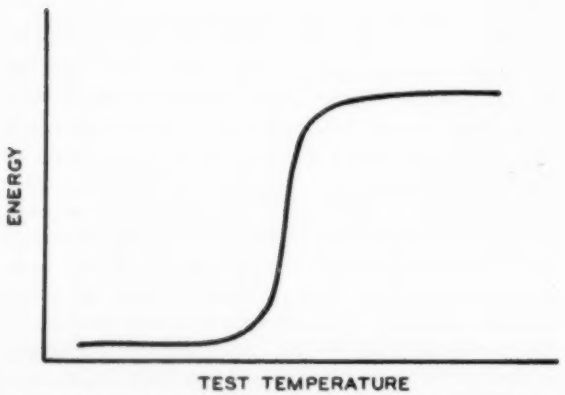

Fig. 3 Hypothesized behavior curve for single specimen

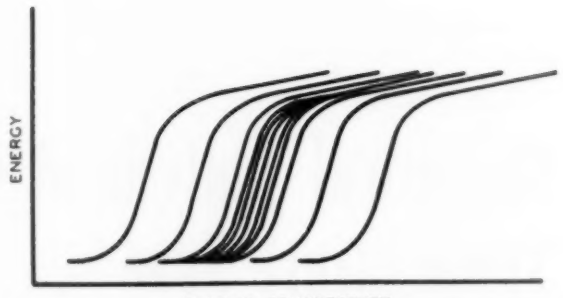

Fig. 4 Hypothesized behavior curves for a number of specimens

It will now be assumed (to be verified later) that the transition temperatures, such as shown in Fig. 4, of a large group of specimens are normally distributed; this means that their distribution follows the pattern portrayed by the curve in Fig. 5, with most of the transition values bunching near the median value and with fewer and fewer values occurring as the distance from the median increases. Of particular interest is the median (in this case, also the mean) transition temperature, which occurs at the peak of the distribution curve.

Because of the apparent steepness of the curves in the transition zone, it is convenient to designate the behavior of any particular specimen as either tough or brittle, for the energy values are either relatively high or very low. In those cases in which intermediate values are obtained, the behavior will be called half tough and half brittle. From the normal distribution curve of Fig. 5, it is possible to determine directly the percent of specimens that would behave in a brittle manner at any testing temperature in the transition zone. The relationship between brittle expectancy and testing temperature is shown in Fig. 6. The curve drawn is called the cumulative normal distribution curve and is simply the

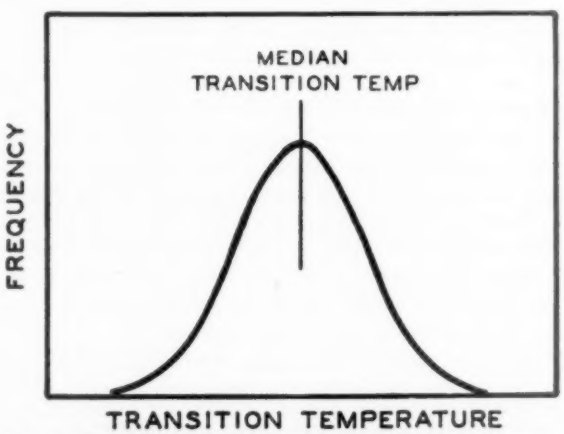

Fig. 5 Hypothesized distribution of transition temperatures

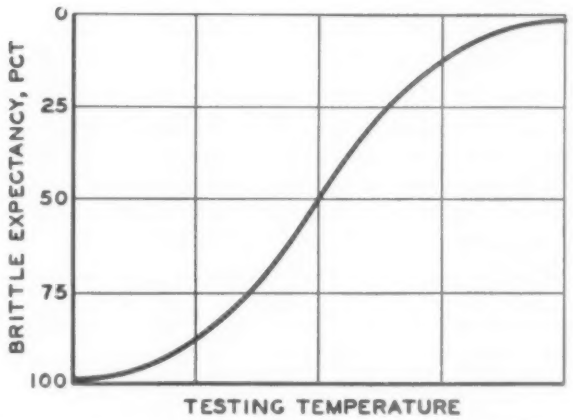

Fig. 6 Expectancy of brittle behavior in the transition-temperature range

integral of the curve in Fig. 5. The median transition temperature in Fig. 5 corresponds to the 50% brittle-expectancy point in Fig. 6.

The pattern of behavior that has just been described represents a situation arising in many fields of research in which a characteristic (here, transition temperature) is conceived to be normally distributed among the individuals of a population, but measurement of any one individual can show only whether the characteristic is above or below a certain level. Thus, in testing insecticides, a critical dose is associated with each insect, but it cannot be measured. One can only try some dose and see whether or not the insect is killed, that is, whether the critical dose for that insect is less than or greater than the dose selected.

The common procedure in experiments of this kind is to divide the sample of specimens into several groups and to test each group at a chosen level, in order to determine the sample probability of an event occurring at each level. This is the technique that was followed in this investigation except for the earlier testing.

One further refinement must be mentioned. A special graph paper, called probability paper, is available on which the curve of Fig. 6 will plot as a straight line. A line is then fitted to the points representing percent brittle behavior at each temperature and a calculation is made to determine whether the scatter of these points about the line is likely to be due just to chance. If the scatter appears to be due to chance, then there is no reason to suspect that our original assumption of normality is false, and this method of analysis may be conveniently used.

The use of this method is illustrated in the following section on the results obtained in the testing of an AISI 1019 steel.

CALCULATING THE REGRESSION LINE

An electric-furnace, aircraft-quality AISI 1019 steel was obtained which was made by fine-grain practice and had the following chemical composition: 0.17 C, 0.82 Mn, 0.008 P, 0.013 S, 0.32 Si and 0.032 acid-soluble Al. A 2-in.-square bar of this material was homogenized at 2300° F for 24 hr, was cut into specimen blanks and the blanks were normalized at 1600° F for 90 min. Longitudinal keyhole Charpy specimens were cut from the blanks, and all specimens were randomized so as to mix them thoroughly and thus avoid possible differences in behavior due to the effect of systematic variations in material. The specimens were also randomized with respect to drilling order to minimize any systematic variation due to drill wear.

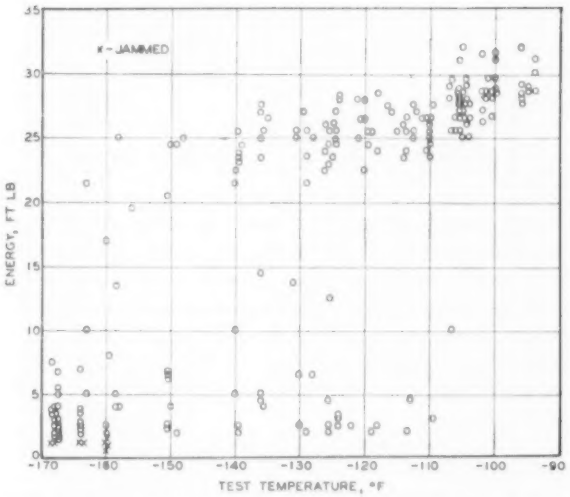

Fig. 7 Keyhole Charpy impact test results for AISI 1019 steel

The results of the 200-odd impact tests that were performed on this bar are shown in Fig. 7. A few of the specimens jammed in the impact machine during testing, but it was obvious from their fracture appearance that they broke in a completely brittle manner. It will be noted that there are relatively few values between 10 and 15 ft-lb. In this first run, the specimens were not tested in groups at specific temperatures as was subsequently done. However, the results can be grouped within specific temperature intervals, each interval being no more than 2 or 3° F wide, and the percent brittle behavior can be determined for each of these small temperature ranges. For determining the percent brittle behavior of this steel, those specimens that absorbed less than 10 ft-lb of energy were called brittle, those that absorbed 10 to 15 ft-lb, inclusive, were called half tough and half brittle, and those that absorbed more than 15 ft-lb were called tough. A plot of these percentages of brittle behavior versus testing temperature is shown in Fig. 8 on arithmetic probability paper. The numeral by each point represents the number of tests conducted at each temperature, i.e., over each small temperature range. The arrows indicate that all of the specimens in that group behaved in a tough or in a brittle manner, as the case may be; these specific percentages could not, therefore, be plotted, due to the nature of the chart.

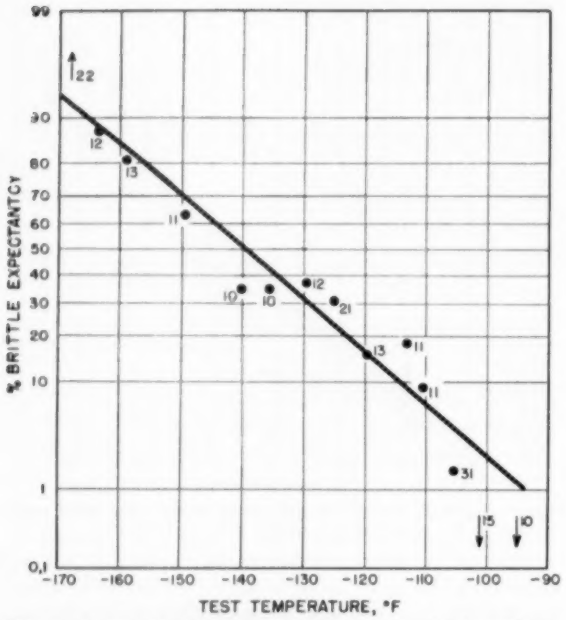

Fig. 8 Regression line for AISI 1019 steel, calculated from data of Fig. 7

The line of best fit or the regression line through these points is determined by calculation using standard statistical procedures (probit analysis) set forth by Bliss,[2, 3] by Fisher and Yates,[4] or, more recently, by Finney.[5] To summarize briefly, a provisional or trial line is fitted by eye to the data, and the percent brittle behavior as indicated by the trial line is noted for each test temperature. The expected probits* corresponding to these percentages are determined from a table of probits[4, 5] (expected probits are obtained also for those cases in which 0 or 100% brittle behavior is obtained). Working probits, y, and weighting coefficients, w/N, are then obtained from tabulated values of the expected probits. The weight assigned to each point is calculated by multiplying the weighting coefficient, w/N, by the number of tests, N, employed to determine the point.

Letting x equal the test temperature, the following quantities are then determined:

$$\Sigma(wx),\ \Sigma(wy),\ \Sigma(wx^2),\ \Sigma(wy^2),\ \Sigma(wxy)$$

where Σ designates a summation of all the indicated quantities. Thus,

$$\Sigma(wx) = w_1x_1 + w_2x_2 + w_3x_3, \text{ etc.}$$

The weighted averages of x and y are

$$\bar{x} = \frac{\Sigma(wx)}{\Sigma(w)} \qquad \bar{y} = \frac{\Sigma(wy)}{\Sigma(w)}$$

The regression coefficient or the slope of the line, b, expressed in standard deviations per ° F, is calculated from

$$b = \frac{\Sigma(wxy) - \bar{x}\Sigma(wy)}{\Sigma(wx^2) - \bar{x}\Sigma(wx)}$$

The estimated standard deviation of the population, σ, in ° F is equal to $1/b$. This standard deviation is equivalent to the temperature interval between 50 and 84.1% or between 50 and 15.9% brittle expectancy and hence is a measure of the width of the transition range. For the data of Fig. 8, $b = -0.0507$ and $\hat{\sigma} = 1/b = 19.7°$ F.

The temperature at which 50% brittle behavior is obtained will be called the median transition temperature, $\bar{x}_{50}$, and will be calculated as follows:

$$\bar{x}_{50} = \bar{x} - \frac{\bar{y} - 5.00}{b}$$

For the data of Fig. 8, $\bar{x}_{50} = -139.6°$ F.

The position of the regression line is thus determined from the calculated values of $\hat{\sigma}$ and $\bar{x}_{50}$. It should be mentioned that the regression line should actually be determined by successive approximations. The line determined by the first analysis becomes the trial line for the second analysis, and so on. Whether this is necessary depends on how well the trial line that has been drawn by eye agrees with the regression line obtained by calculation. With a little practice, good agreement is usually obtained, and only one cycle of calculations is therefore necessary. Occasionally, however, the first guess may be poor, and, in that case, another calculation may be advisable.

The parameters $\hat{\sigma}$ and $\bar{x}_{50}$ are of particular interest for the regression line. $\bar{x}_{50}$ is the best estimate of the exact middle of the transition range, at which the likelihood of brittle behavior is 50%. As mentioned before, $\hat{\sigma}$ is a measure of the width of the transition range. Since the width of the transition range is infinite according to the probability curve, the width may be arbitrarily designated as the difference in temperature between the 10 and 90% (or any other) brittle-expectancy points. This width may be taken from the regression line or may be calculated. The 10 and 90% brittle-expectancy points are located at $\pm 1.28\hat{\sigma}$ from $\bar{x}_{50}$. The total width of the range from 10 to 90% brittle expectancy is therefore $2 \times 1.28\hat{\sigma}$ or $2.56\hat{\sigma}$. For the data of Fig. 8, the width of the range is 2.56×19.7 or 50.4° F.

TESTING THE ASSUMPTION OF NORMALITY

To test the original assumption of normality, it is necessary to know whether the experimental points vary significantly from the straight line, that is, whether the departure of the brittle-percentage points from the line is more than could be expected from chance variation.

A nonrandom distribution of the points might indicate nonlinearity and hence nullify the original hypothesis of behavior or it might indicate that some uncontrolled variable is causing a greater variation about the line than would be expected from random variations in sampling.

* Probits are probability units corresponding to the given percentages and are used to transform the cumulative frequency distribution curve to a straight line. The probability units used are standard deviations which are increased by 5 to avoid negative values.

The fit of the observed points to the regression line is determined by the chi-square (χ^2) test as follows:

$$\chi^2 = [\Sigma(wy^2) - \bar{y}\Sigma(wy)] - b[\Sigma(wxy) - \bar{x}\Sigma(wy)]$$

If the χ^2 value* is less than the tabled value of χ^2 at the selected probability level, then it may be assumed that the data are homogenous, i.e., that the points do not vary significantly from the straight line.

In the present case for Fig. 8, $\chi^2 = 5.08$ and the tabled value of χ^2 for 12 deg of freedom at the 0.05 probability level is 21.0 (only 5% of the time would a value as high as 21 be obtained if the scatter of the points were random). The scatter of the points about the line is therefore judged to be random, and the data are considered homogenous.

χ^2 values have been determined for 33 such regression lines to date on six different steels, and in only two cases was the χ^2 value excessive (indicating heterogeneity). This indicates that the behavior hypothesized must approximate rather closely the behavior actually obtained.

UNCERTAINTIES OF MEDIAN TRANSITION TEMPERATURE AND TRANSITION RANGE

The median transition temperature, $\bar{x}_{50}$, and the slope, b, or its reciprocal, $\hat{\sigma}$, are only best estimates and may vary within certain limits. The variances of $\bar{x}_{50}$ and of b are calculated as follows:

$$\text{variance of } \bar{x}_{50} = s_{\bar{x}_{50}}^2 = 1/b^2\left[\frac{1}{\Sigma(w)} + \frac{(\bar{x}_{50} - \bar{x})^2}{\Sigma(wx^2) - \bar{x}\Sigma(wx)}\right]$$

$$\text{variance of } b = s_b^2 = \frac{1}{\Sigma(wx^2) - \bar{x}\Sigma(wx)}$$

For the data of Fig. 8, $s_{\bar{x}_{50}}^2 = 4.89$; therefore the standard error of the median transition temperature = $s_{\bar{x}_{50}} = 2.21°$ F.

The true median transition temperature therefore lies within the limits $\pm ts_{\bar{x}_{50}}$. Selecting Student's t value at the 0.05 probability level for an infinite number of degrees of freedom (providing χ^2 is not excessive†), it may be stated that $\bar{x}_{50} = -139.6 \pm 4.3°$ F with 95% certainty. These limits indicate the *precision* of the estimate of $\bar{x}_{50}$; the closer together the limits, the more precise is the estimate.

Similarly, the true slope lies within the limits $b \pm t_{0.05}\, s_b$ with 95% certainty:

$$-0.0507 \pm 1.96 \times 0.0051 = \text{limits of } -0.0607 \text{ and } -0.0407$$

The limits in terms of $\hat{\sigma}$ are the reciprocals of the above values or 16.5 and 24.6° F. The latter quantities are multiplied by 2.56 to find the 95% confidence limits on the range from 10 to 90% brittle expectancy. These limits are 42 and 63° F. As noted before, the best estimate of the range is 50.4° F.

COMPARING SLOPES AND x_{50} VALUES

Frequently, it will be desired to compare two or more regression lines in order to determine whether their slopes (i.e., their transition ranges) or $\bar{x}_{50}$ values differ significantly or whether the differences obtained are simply the consequence of chance variations.

To determine whether the slopes of two lines are significantly different, when the data are homogenous, the following χ^2 test is used where χ^2 has one degree of freedom:

$$\chi_b^2 = \frac{(b_1 - b_2)^2}{s_{b_1}^2 + s_{b_2}^2}$$

where b_1 and b_2 are the respective slopes and s_{b_1} and s_{b_2} are the respective standard errors of the slopes.

If the data of one or both of the lines are heterogeneous (excessive scatter as indicated by χ^2 test for homogeneity), the t test is used, where the degrees of freedom in t are the sum of the degrees of freedom in both the regression lines:

$$t = \frac{b_1 - b_2}{(s_{b_1}^2 + s_{b_2}^2)^{1/2}}$$

If more than two slopes are to be compared, the following formula, proposed by Bliss,[3] may be used:

$$\chi_b^2 = \Sigma[A_i(b_i - \bar{b})^2]$$

where

$A_i = 1/s_b^2$ for the i-th line.
b_i = slope of the i-th line.
$\bar{b}$ = weighted average slope of all the lines.

This formula reduces to

$$\chi_b^2 = \Sigma(A_i b_i^2) - \frac{(\Sigma A_i b_i)^2}{\Sigma(A_i)}$$

The number of degrees of freedom in χ^2 is $k-1$ for k regression lines.

If χ_b^2 does not exceed the tabled value of χ^2, the slopes may be considered homogeneous (not differing significantly from each other) and may be averaged to obtain a best estimate of the slope. The mean slope, $\bar{b}$, of all the lines is

$$\bar{b} = \frac{\Sigma(A_i b_i)}{\Sigma(A_i)}$$

The estimate of the standard error of the mean slope, $s_{\bar{b}}$, is

$$s_{\bar{b}} = \sqrt{\frac{1}{\Sigma(A_i)}}$$

Confidence limits are obtained as before, and the mean slope and its limits may be expressed in terms of width of the transition range.

A group of median transition temperatures may be analyzed and compared using similar formulas in which

* The degrees of freedom in χ^2 were calculated as two less than the number of experimental points. When the expected number of tough or brittle specimens at one or more temperatures is small, however, both Bliss and Finney suggest alternate methods for approximating the number of degrees of freedom.

† In those cases where χ^2 was excessive, the variances of $\bar{x}_{50}$ and of the slope, b, were inflated by the factor, χ^2/n, where n = degrees of freedom in χ^2. Also, when χ^2 was excessive, confidence limits were determined by using a t value with the number of degrees of freedom in χ^2.[4,5]

A_i equals the reciprocal variance of $\bar{x}_{50,i}$ $\frac{1}{s_{\bar{x}_{50,i}}^2}$, for each line, and in which $\bar{x}_{50}$ is substituted for the slope, b.

JUDGING DIFFERENCES BETWEEN SLOPES AND x_{50} VALUES

When the χ^2 test used above indicates that the slopes or $\bar{x}_{50}$ values are not homogeneous (excessive χ^2 value), then it is usually desirable to determine which slopes or $\bar{x}_{50}$ values are significantly different and by how much.

When three or more values are being compared, it is not advisable to determine these differences by repeated t tests, because of the effect of such a practice on the probability level. If one statement is selected at random from all the statements about differences that can possibly be made, the probability of this statement being true is $1 - \alpha$ for the ordinary t test, where α is the selected level of significance. A *maximum* difference that is evaluated, however, does not have this probability. Another way of saying this is that the distribution of the maximum difference selected from a set of contrasts is not the same as the distribution of any one difference selected at random from the set.

A method of constructing intervals has been developed by Scheffé[6] for making any linear comparisons suggested by the data, including any groupings desired. By using this method, the probability that the intervals calculated *all* cover the true values of the corresponding contrasts or differences can be fixed at any desired value. This method and an example of its use is outlined below.

A particular contrast, θ, among some (or all) of a set of k means, μ_i, is defined by the equation

$$\theta = \sum_{i=1}^{k' \leq k} c_i \mu_i$$

Where $\Sigma c_i = 0$.

Calling $\hat{\theta}$ the "estimate of θ" and $\bar{x}_i$ the average value from the data that estimates μ_i,

$$\hat{\theta} = \Sigma c_i \bar{x}_i$$

For example, if there are seven average values ($k = 7$) and it is desired to estimate the difference between the first two and the last three, then

$$\hat{\theta} = \frac{\bar{x}_1 + \bar{x}_2}{2} - \frac{\bar{x}_5 + \bar{x}_6 + \bar{x}_7}{3}$$

In this case $c_1 = c_2 = {}^1/_2$ and $c_5 = c_6 = c_7 = -{}^1/_3$ so that $\Sigma c_i = 0$.

As in the usual confidence interval statements using Student's t, it is desired to add and subtract a quantity to $\hat{\theta}$ so that the resulting intervals for all contrasts, $\hat{\theta}$, have a 95% probability of covering all the true differences, θ. This does not mean that only 95% of the calculated intervals in a particular experiment* are expected to cover the corresponding θ values, but that, in 95% of all experiments, *all* the intervals will cover their respective true values.

The answer is given in the following form: for all contrasts in an experiment,

$$\text{Probability } \{(\hat{\theta} - C) < \theta < (\hat{\theta} + C)\} = 1 - \alpha$$

where $1 - \alpha$ is the chosen confidence level, and C is defined as a certain constant, S, times the estimated standard error of the particular $\hat{\theta}$ under consideration. Thus, $C = S\,\hat{\sigma}_{\hat{\theta}}$.

If the $\bar{x}_i$ values are statistically independent, as they usually are, the estimate of this standard error will be

$$\hat{\sigma}_{\hat{\theta}} = [\Sigma c_i^2 \hat{\sigma}_{\bar{x}_i}^2]^{1/2}$$

The quantity S is shown by Scheffé to be:

$$S = [(k - 1)F_{\alpha,\, k-1,\, f}]^{1/2}$$

where F is the upper alpha point (α being the selected level of probability) of the F-distribution (tabled in every statistical text) with $k-1$ degrees of freedom in the numerator, and f degrees of freedom for the estimate of the error standard deviation in the denominator.

The following example will demonstrate the use of this method for making comparisons among a group of means. To evaluate the effect of slightly different specimen preparations on the slope of the regression line, seven preparations were used on one steel, and mean slopes, b (neglecting minus signs), and their estimates of standard error, s_b, were obtained, as in Table 1. A χ^2 test indicates that these slopes are heterogeneous (χ^2 probability of <0.001), so it is desired to determine which slopes may be considered significantly different.

Table 1—Slopes of Regression Lines for Different Specimen Preparations

Preparation	b	s_b	*Number of tests*	*Number of test temperatures*
H	0.0814	0.0148	280	14
J	0.1570	0.0183	199	5
K	0.0731	0.0161	100	3
L	0.0922	0.0156	100	6
M	0.0595	0.0117	102	6
N	0.1604	0.0294	100	5
I	0.0936	0.0162	100	5

Inspection of the data of Table 1 suggests that Preparations H, K, L, M and I have true slopes that are about the same, and that the slopes for J and N are both higher. The slope for Preparation J will first be compared with those for H, K, L, M and I. In this example, the average slope for H, K, L, M and I is not the sum of these slopes divided by 5, because each slope is weighted differently. Instead, the average of these 5 slopes is $\Sigma A_i b^* / \Sigma A_i$, as explained previously, or 0.0771.

Therefore,

$$\hat{\theta} = 0.1570 - 0.0771 = 0.0799$$

now,

$$k = 7 \text{ and } F_{0.05,\, 6,\infty} = 2.09$$

$$S = [(k - 1)F]^{1/2} = 3.54$$

$$c_J = 1 \text{ and } c_H = c_K = c_L = c_M = c_I = -{}^1/_5$$

* An "experiment" is a collection of k means and k may vary from one experiment to another.

* A_i is the *estimated* weight of the estimated slope, b, of each regression line; thus $A_i = 1/s_b^2$. This approximation to the true weight makes the calculation which follows inexact, but this defect is not believed to be serious for the volume of data available.

In this problem, $\hat{\sigma}_{\bar{x}_i}$ is equivalent to each s_b value, so

$$\hat{\sigma}_{\hat{\theta}}^2 = \Sigma c_i^2 \hat{\sigma}_{\bar{x}_i}^2 = \frac{\overline{0.0183}^2 + \overline{0.0148}^2 + \overline{0.0161}^2 + \overline{0.0156}^2 + \overline{0.0117}^2 + \overline{0.0162}^2}{25}$$

$$\hat{\sigma}_{\hat{\theta}} = 0.0195$$

Then,

$$C = S\hat{\sigma}_{\hat{\theta}} = 3.54 \times 0.0195 = 0.0690$$

Thus, the true difference, θ, between the slope for J and the mean slope for H, K, L, M and I is judged to be 0.0799 ± 0.0690 with a probability of about 95%, and this is a real difference.

Any other linear comparisons may still be made, and it is known in advance that in 95% of all experiments in which this is done, *all* the intervals calculated cover all the true values. Thus, it is found that the slopes for H, K, L, M and I do not differ significantly from each other (the maximum difference is only 0.0341). The difference between the slope for N and the pooled slope for H, K, L, M and I is judged to be 0.0833 ± 0.1067. This difference is not significant, therefore, at the 95% certainty level. The reason for this, of course, is the larger standard error associated with the slope for N.

THE INFLUENCE OF NUMBER AND DISTRIBUTION OF TESTS ON PRECISION

Whenever impact tests are conducted in order to obtain estimates of transition temperatures, it is important to know how precise (i.e., how well determined) these estimates may be. If the precision is not known, it is problematical whether the differences in transition temperatures that are obtained are real or whether they are simply the consequence of chance variation. The value of statistics lies in its ability to provide an answer with a stated assurance. The width of the transition range is also frequently of interest and, here again, the best evaluation is provided by statistical procedure. The methods that have been described will show how precise the estimates of $\bar{x}_{50}$ and of the range may be when different numbers of tests are performed and when they are distributed in different patterns.

Table 2 shows approximate 95% confidence limits on $\bar{x}_{50}$ for different values of the width of the range from 10 to 90% brittle behavior and for various numbers of specimens when tests are conducted at four to six temperatures which are distributed more or less uniformly along the regression line between temperatures corresponding to about 10 and 90% brittle expectancy. For example, when the range is 38.5° F, the precision of the estimate of $\bar{x}_{50}$ is about ±6.0° F when 50 tests are performed (say 10 tests at each of five temperatures). It will be noted that the precision increases as the number of tests increases and as the range decreases.

Table 2—Approximate 95% Confidence Limits on x_{50} in ° F for Different Ranges and Numbers of Specimens

	Number of specimens			
Range	*100*	*50*	*30*	*18*
25.6	±2.8	±4.0	±5.2	±6.6
38.5	±4.2	±6.0	±7.8	±9.9
77.0	±8.4	±12.0	±15.6	±19.8

Many of the steels tested in this investigation had a range of about 38.5° F. The table shows that when about 18 tests are performed to determine the transition temperature, as is often done in laboratory testing, the precision of the estimate of $\bar{x}_{50}$ is about ±10° F. The smallest difference between two median transition temperatures that can be called significant with 95% certainty is obtained by multiplying all the tabled values by the square root of 2. Thus, for 18 tests and a range of 38.5° F, the smallest significant difference would be $10 \times \sqrt{2}$ or 14° F when the tests are conducted between 10 and 90% brittle expectancy. If three tests are conducted at each of six temperatures spaced 10° F apart, such that $\bar{x}_{50}$ falls near one of the central testing temperatures, the smallest difference between two $\bar{x}_{50}$ values that can be judged real with 95% assurance is about 15.5° F. These values indicate what sort of precision may be expected of the usual transition temperature evaluations. The above presumes that the transition temperatures selected are the best estimates (as obtained by probit analysis). A less precise method of selection will result in increased uncertainties.

When the slope is known, the most precise estimates of x_{50} are obtained by conducting all tests at $\bar{x}_{50}$. This is impossible since neither x_{50} nor the slope is known in advance, but it is interesting to know what precision might be obtained if it were possible. If all tests could be conducted at $\bar{x}_{50}$, the precision of the estimates would be about 90% of the values listed in Table 2. Thus, for 18 tests and a 38.5°F range, the precision would be ± 8.9° F instead of ±9.9° F. This is not a striking improvement. It should be remembered, however, that the precision of the estimate of x_{50} decreases (that is, the confidence limits increase) as the testing temperatures become further removed from the median transition temperature.

The most precise estimate of the width of the transition range is obtained by conducting all tests at two temperatures, namely, half at 6% brittle expectancy and half at 94%.[7] Since at least one brittle or one tough break should be obtained at each temperature, respectively, an average of at least 20 tests would have to be broken at each temperature to obtain these expectancies.

Now, if two regression lines were obtained whose ranges were 38.5 and 77.0° F, respectively (one being twice the other), 32 tests would be required per line under these most favorable conditions (16 at each temperature) in order to be 95% certain that the observed difference was real. (Actually 20 tests would have to be conducted at each temperature because of the above-mentioned restriction.)

Testing at 6 and at 94% brittle expectancy, however, is next to impossible, since these points are very difficult to locate. Percentages closer to 50% are much easier

to locate. If tests were conducted at about 15 and at 85% brittle expectancy, it would take 50 specimens per line to judge the difference between 38.5 and 77.0° F real with 95% certainty. With test temperatures distributed along the regression line, as in most of the work in this program, about 56 specimens would be required.

From these figures, it may be seen that there would be little hope of detecting a real difference between two transition ranges with the few specimens ordinarily used to determine behavior in the transition range, unless the difference were quite large.

When transitional behavior is determined for several plates or heats of one type of steel, the ranges obtained may be pooled, when they appear homogeneous, to obtain a much more precise estimate of the range for this type of steel. The pooled estimate might then be compared with a pooled estimate obtained for some other type of steel or other condition of treatment, and any real differences may then be more readily detected.

SUMMARY

Numerous keyhole Charpy impact tests were conducted in the ductility transition temperature range of several steels. In all these tests, the familiar pattern of behavior was evident, in which either high energy values (portraying tough behavior) or low energy values (portraying brittle behavior) were usually obtained, with few intermediate values. It was found that the relationship representing the percentage of brittle breaks at each temperature coincided, within the limits of error, with a cumulative frequency distribution curve, such as shown in Fig. 6. This curve becomes a straight line when plotted on probability paper (Fig. 8). Behavior in the transition zone is then represented by two parameters of this line: (1) the temperature at which 50% of the specimens behave in a brittle manner, called the median transition temperature and (2) the slope of the line, which may be expressed in terms of the width of the transition range between the 10 and 90% (or any other) brittle-expectancy points.

The best straight line (the least-squares regression line) through the points representing percent brittle behavior at each temperature is obtained by a statistical method called probit analysis, which is described. Use of this method also permits calculation of confidence limits within which the true median transition temperature and the true width of the transition range will lie 95% of the time.

Methods are then described for comparing and for judging differences between two or more regression lines.

Finally, examples are given which indicate how precise, as judged by confidence limits, the estimates of transition temperature and of range may be when different numbers of tests are performed and when they are distributed in different patterns.

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References

1. Vanderbeck, R. W., "Evaluating Carbon Plate Steels by the Keyhole Charpy Impact Test," The Welding Journal, **30** (1), Research Suppl., 59-s to 64-s (1951).
2. Bliss, C. I., "The Calculation of the Dosage-Mortality Curve," *Ann. Appl. Biol.*, **xxii**, 134–167 (1935).
3. Bliss, C. I., "The Comparison of Dosage-Mortality Data," *Ibid.*, **xxii**, 307–333 (1935).
4. Fisher, R. A., and Yates, F., "Statistical Tables for Biological, Agricultural, and Medical Research," Oliver and Boyd (1949).
5. Finney, D. J., "Probit Analysis," 2nd ed., Cambridge Univ. Press (1952).
6. Scheffé, H., "A Method for Judging All Contrasts in the Analysis of Variance," *Biometrika*, **40** (1+2), 1–18, (1953).
7. Eisenhart, C., Hastay, M. W., and Wallis, W. A., "Techniques of Statistical Analysis," McGraw-Hill Book Co., New York, p. 352 (1947).

Europeans Studying U. S. Welding Techniques

Welding techniques and uses developed by American industry, as well as U. S. methods of facilitating adoption of new techniques by management and labor, are being studied by specialists from 11 Western European countries.

The study is jointly sponsored by the Organization for European Economic Cooperation and the Mutual Security Agency under MSA's productivity and technical assistance program.

All of the participants are active in the International Institute of Welding. Among them are engineers, metallurgists, plant officials, and representatives of research institute and laboratories from Austria, Belgium, Luxembourg, Denmark, France, Western Germany, Italy, The Netherlands, Portugal, Switzerland and the United Kingdom.

A highlight of the U. S. study will be attendance at the National Spring Technical Meeting of the American Welding Society in Houston, Tex., from June 16th through June 19th.

The team is divided into two groups for specific studies. Group A, composed primarily of professors and members of research institutes and laboratories, is concentrating on U. S. methods of training welding engineers, foremen and operatives; welding research organization and methods; welding inspection and quality testing.

Group B, made up of industry representatives and engineers, is observing the practical application of new welding tech-

(*Continued on page 346-s*)

Mechanics of the Explosion Bulge Test

A semiworks-scale test of weldments featuring simple geometry and biaxial loading requiring simple equipment and experimental techniques

by Carl E. Hartbower, Lt. CEC. USNR-R

INTRODUCTION

THE need for a semiworks-scale test of weldments featuring simple geometry and controlled loading led to the adoption of bulge-test methods. Both tube and bulge tests permit controlled biaxial loading: tubes require axial tension applied concomitantly with internal hydrostatic pressure and bulges require fluid or gas pressure on edge-supported diaphragms. Although the tube test has the advantage of providing uniform strain over a relatively extensive test area, massive equipment and elaborate gripping devices are required to avoid end-bending effects.[1] Consequently, tube tests are extremely expensive and have been limited primarily to fundamental research in the field of applied mechanics. The advantages of bulge tests, on the other hand, lie in the simplicity of equipment and experimental techniques. The principal disadvantage is the relatively small area of pole region which may be classed as being effectively under uniform strain. Bulges in sheet metal are produced by hydraulic pressure applied to a test diaphragm clamped over a circular or elliptical opening. The extension of hydraulic bulge testing to full thicknesses of ship plate was accomplished by the detonation of an explosive suspended in air over the test plate. The explosive is used only as an expedient method for obtaining the large force necessary to develop a bulge in thick plate. The objective of bulge testing welds in full thicknesses of ship plate is to provide semiworks-scale structural tests incorporating uniform and controlled loading of weld, HAZ, and parent plate and to thereby determine the factors controlling weldment performance.

Initial studies of flow[2] and fracture[3] in welded bulges have established the merits and usefulness of the test method. Study of the distribution of plastic strain in various weld and base-metal combinations was made by measuring the distortion of a 20-line-to-the-inch grid applied to the surface of the test plate by the photogrid process. Measurements showed that the stress and strain state imposed by the loading conditions are not always accepted by the weld joint. Depending upon the relative flow strengths of weld and base metal, a system of stress and strain entirely foreign to the remainder of the structure may be developed in the weld and near-weld regions. A study of the fracture characteristics of various weld and base-metal combinations indicated a wide range of performance which appeared to be determined by the properties of the deposited weld metal rather than the HAZ. Tests have been conducted at temperatures ranging from approximately −100 to +200° F. Results indicated that the explosion bulge test is primarily an evaluation of the crack initiation stage of weldment failure (catastrophic failure of welded structures may be considered to occur in two stages—crack initiation and crack propagation). Inasmuch as external mechanical notches are absent and the stress conditions of the bulge are essentially biaxial, extensive deformation is developed in most weldments at ordinary temperatures of service (32° F and above) prior to the initiation of fracture. Such data are applicable to the case of service entailing extensive deformation (explosion, collision, etc.). Data significant to structures which operate at elastic loads are obtained by causing fracture to occur at near-zero levels of deformation. This is achieved by lowering the temperature, thus introducing a resistance to flow such as is obtained under conditions of severe triaxiality. The requirement of low temperature to initiate failure in tough welds at low levels of deformation results in extensive fracturing of the base plate since most structural materials have an inherently low resistance to crack propagation at the subzero temperatures necessary for crack initiation. Crack initiation at a near-zero level of strain was found to occur at widely different temperatures depending upon the notch toughness of the test weld. Temperature thus serves as a basis of evaluation—the weld requiring the lowest temperature to initiate fracture is deemed most desirable.

Information obtained from bulge tests of sheet metal[4]

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This paper was written while the author was employed at the Naval Research Laboratory, Washington, D. C. The opinions or assertions contained herein are the private ones of the writer and are not to be construed as official or reflecting the views of the Navy Department or Naval Service at large.

Lt. Hartbower received Special Honorable Mention for the second successive year in competition for the Annual Award of the Chief of the Navy Bureau of Yards and Docks with this paper.

provided a guide in establishing the present technique; however, the novel application to heavy plate and to welds involving differential straining in the various components of the weld zone posed new problems which required detailed study of the mechanics of test. As straining progresses in the hydraulic bulging of sheet metals, the magnitude of the strain at any given level of deformation varies from zero at the clamped edge to a maximum at the apex of the bulge. The extent of the pole region over which the strains are substantially uniform is determined by the thickness-to-diameter (span) ratio and the degree of deformation to which the bulge is subjected. At a certain critical level of deformation, a condition of instability develops.[5] When unstable flow occurs, straining becomes localized, the geometry of the test specimen changes and the state of stress in that portion of the specimen undergoing plastic flow is no longer under control. In the hydraulic bulging of circular diaphragms, instability is identified by an increase in deformation with no increase in pressure. In the formation of an elliptical bulge the strain ratio at the crown of the bulge changes continuously, gradually approaching one. Thus, in the elliptical bulge the limiting condition is determined by that stage of deformation at which there is an excessive alteration in the strain ratio; i.e., a loss of control over the stress state. The following report is concerned with the mechanics of flow in the bulging of plate, particularly the effect of progressive straining (by multiple shots) in producing instability and localization of flow.

BULGING BY MEANS OF EXPLOSIVES

The extension of hydraulic bulge testing techniques to full thicknesses of ship plate was accomplished by the detonation of an explosive suspended in air over the test plate (Fig. 1). The test plate was supported by a 3-in. thick armor saddle containing either a circular (r = 6 in.) or an elliptical (a = 7.5 in., b = 4.8 in.) opening (Fig. 1 (*a*)). To develop approximately uniform loading over the entire unsupported area of the test plate, the explosive was shaped to the form of a wafer of the same configuration as the opening in the saddle plate (a = 6.5 in., b = 3.8 in. for elliptical charges and r = 5 in. for circular charges). The explosive was fired in air at a distance of 12 to 24 in. from the test plate; the standoff was regulated and the charge positioned by the simple expediency of a pasteboard carton cut to the desired height and marked for

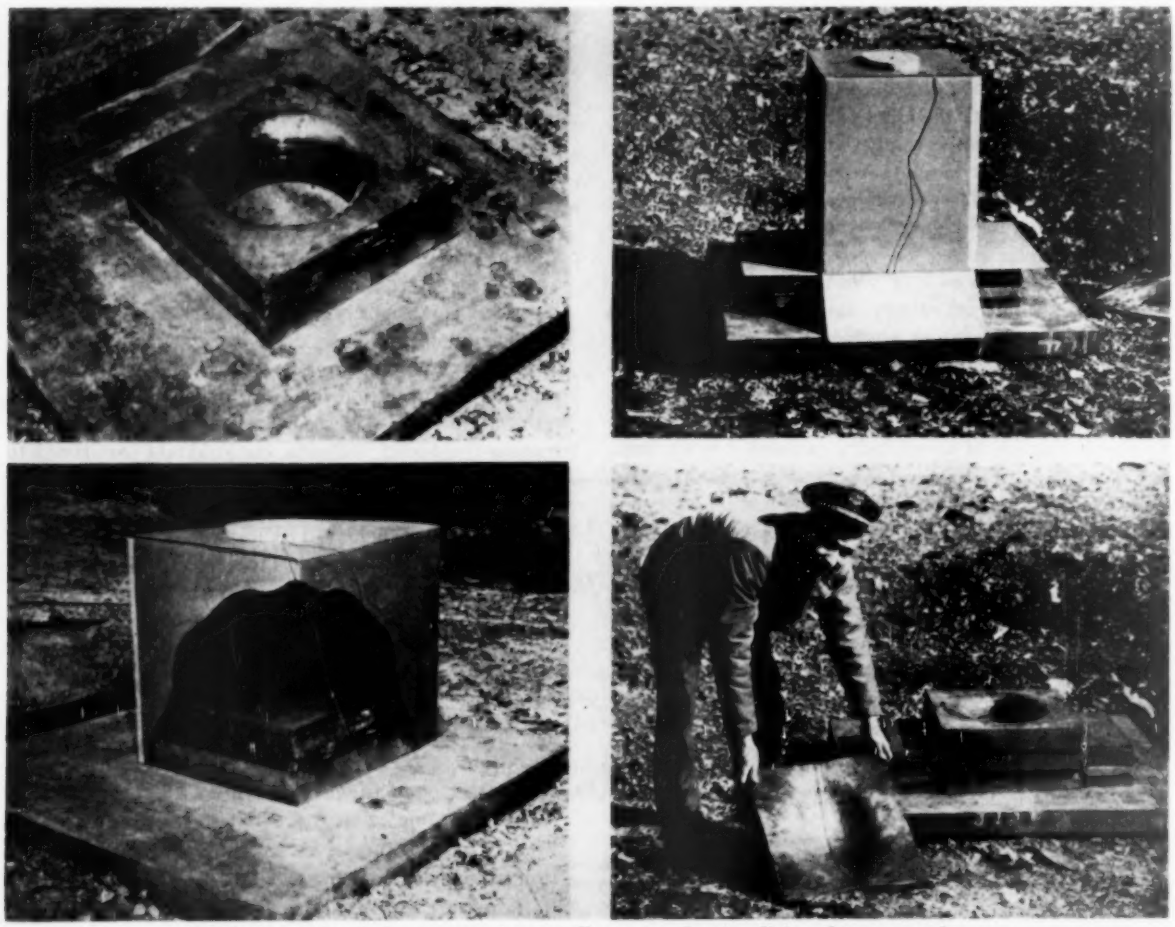


Fig. 1 Explosion bulge test equipment illustrates the simplicity of test procedures

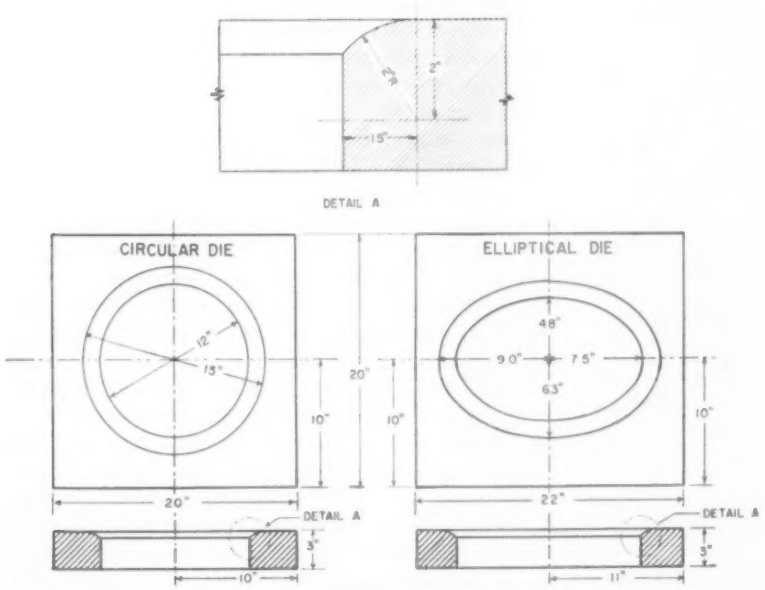


Fig. 1 (a) Details of the dies

location of the charge on one end. The air blast was deemed to produce a uniformly distributed pressure wave normal to the plate surface. In that the unsupported area of the 20- x 20-in. test plate was only 28% of the total area, the high pressure applied to the supported portions of the plate effectively clamped the edges to the saddle (Fig. 2).

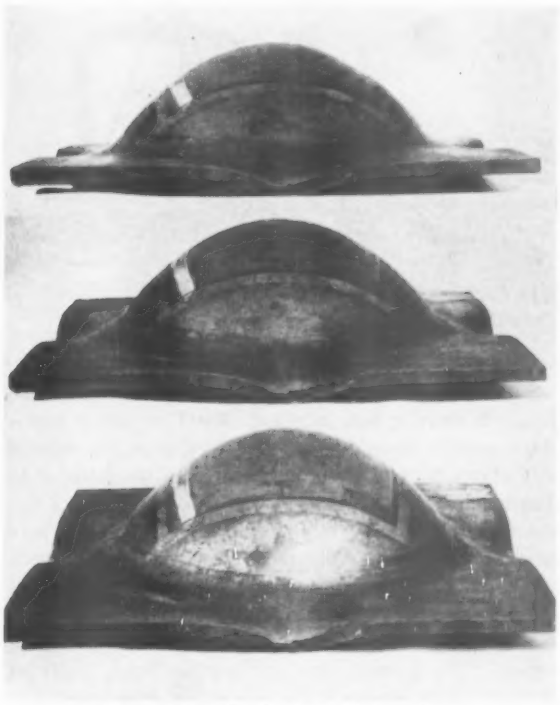


Fig. 2 Circular bulge in $^3/_4$-in. plate

Three views of a single bulge show the effectiveness of edge clamping by explosive action.

The explosive is used simply as a means of obtaining the high forces required to develop bulges in thick plate. The depth of bulge produced by various combinations of weight and standoff of explosive are indicated by the empirical relationship of Fig. 3. Good reproducibility of test conditions are demonstrated. The use of applied energy (weight of explosive, number of shots, etc.) as the criterion of performance gives an integrated "order of merit" which is difficult to resolve into engineering parameters; whereas measurement of either the biaxial strains developed in the surface of the bulge or reduction of thickness provide data of direct engineering significance. Consider, for example, the hypothetical case of two welds of the same terminal ductil-

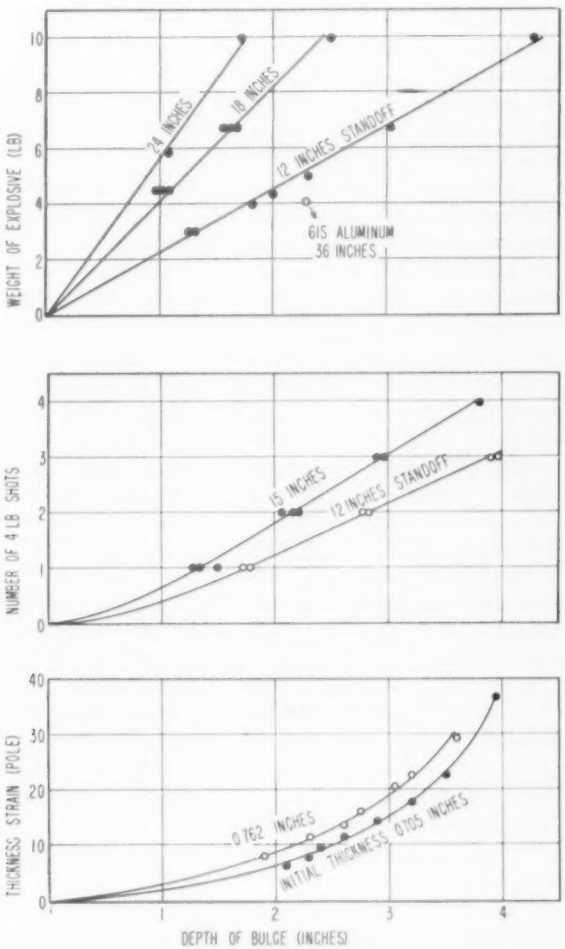


Fig. 3 Depth of bulge

Various relationships showing the reproducibility of test results and criteria that may be used in evaluating performance.

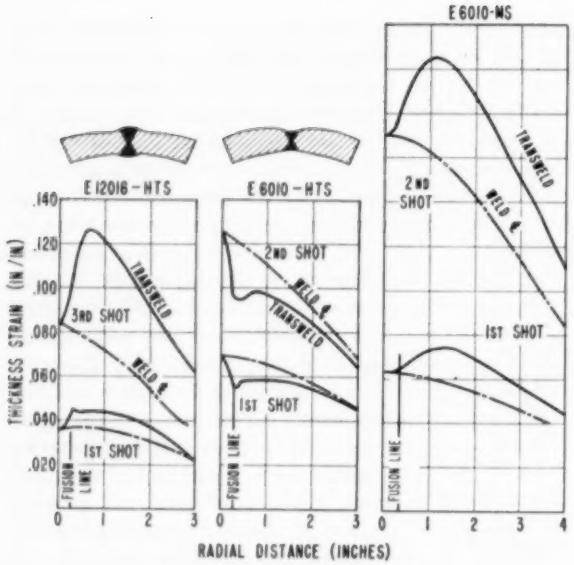


Fig. 4 Strain distributions

The effect of weld and base metal flow strength in restraining plastic flow are indicated.

ity but of different flow strength; while both welds will fracture at the same level of strain, the weld with the higher flow strength requires greater energy to develop the fracture strain. By separate observations of "restraint to flow" and "flow at fracture" it is possible to break down the energy value into two parameters of engineering significance.

Figure 4 illustrates the restraining effect of an E12016 weld deposit in high-tensile steel—3 shots (4 lb at 15 in.) were required to produce the same general level of deformation as 2 shots against an E6010-HTS weldment. Likewise, a marked difference in resistance to flow is demonstrated between different types of structural materials; for example, 2 shots against the E6010 weld in mild steel developed almost twice the deformation produced by 2 shots against E6010 in HTS. Thus, the energy required to produce similar amounts of bulge (strain) varies greatly depending on the stiffness of the plate or weldment. In keeping with the principle that the explosive is used only as a means of obtaining the high forces required to bulge thick plate, a fixed weight of charge and standoff are selected for each series of tests according to the requirements of the material being bulged. In bulging $^3/_4$-in. thick weldments of mild and high-tensile steel, a standard condition of 4 lb of explosive at 15-in. standoff was selected; while in bulging $^3/_4$-in. thick 61S aluminum plate with a 4-lb charge, the standoff was increased to 36 in. In order to minimize the rise in temperature due to adiabatic deformation, an increment loading technique was employed consisting of a succession of explosions (4 lb charge at 15 in. standoff) until the desired strain level obtained or fracture occurred.

STRESS-STRAIN CONDITIONS IN BULGES OF HEAVY PLATE

The distribution of plastic strain in the bulge surface was determined by measuring the distortion of a 20-line-to-the-inch grid applied to the plate by the photogrid process. The measurement was made by means of a microscope containing a crosshair and mounted on a micrometer slide. The micrometer-microscope in turn was mounted on a platform supported by three adjustable legs (Fig. 5). In the case of elliptical bulges, the strains were measured in the convex surface along lines parallel to the major and minor axes. The component parallel to the minor axis (the direction of major applied stress) was designated e_1 and the component perpendicular to the minor axis, e_2. A schematic of strain distribution has been used as a means of ready reference and orientation for the reader. The schematic includes elements scaled to represent grid distortion. Squares indicate equal extensions in all directions and rectangles indicate greater strain in one direction than the other. In the case of the circular bulge, the convention was adopted of designating the component radial to the pole as e_1 and the circumferential component at any point on a radial line as e_2. Measurement of the component of strain through the thickness (e_3) was made by micrometer caliper readings at regular intervals along the major and minor axes of the ellipse or along radial lines in the circular bulge. The natural strain in the thickness direction was computed from the expression $\log_e To/T$ where To and T are the original and final thicknesses, respectively.

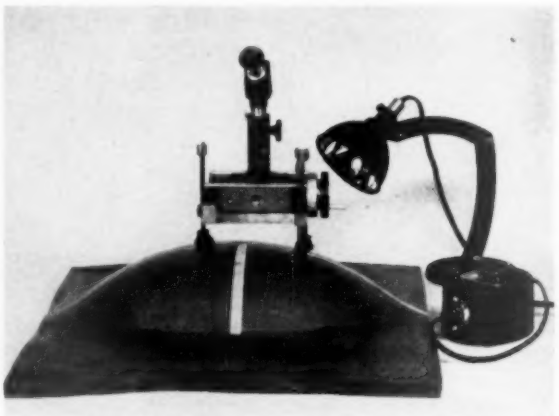


Fig. 5 Measurement of surface strain

Since span-to-thickness ratio in bulge testing of sheet metals is usually held at about 300:1 to assure membrane conditions, and in bulging thick plate the ratio is only about 20:1, it is to be expected in the latter case that bending conditions prevail. A comparison of the strain states existing in the concave and convex surfaces of thick-plate bulges confirmed the presence of bending. For example, in the early stages of elliptical bulging, measurement of e_2 in the concave surface indicated small compressive strains over the entire pole region. The e_2 component, on the other hand, consisted of small tensile strains in the pole region which were approximately 50% of the corresponding strain in the convex surface. See Fig. 6 for a schematic representa-

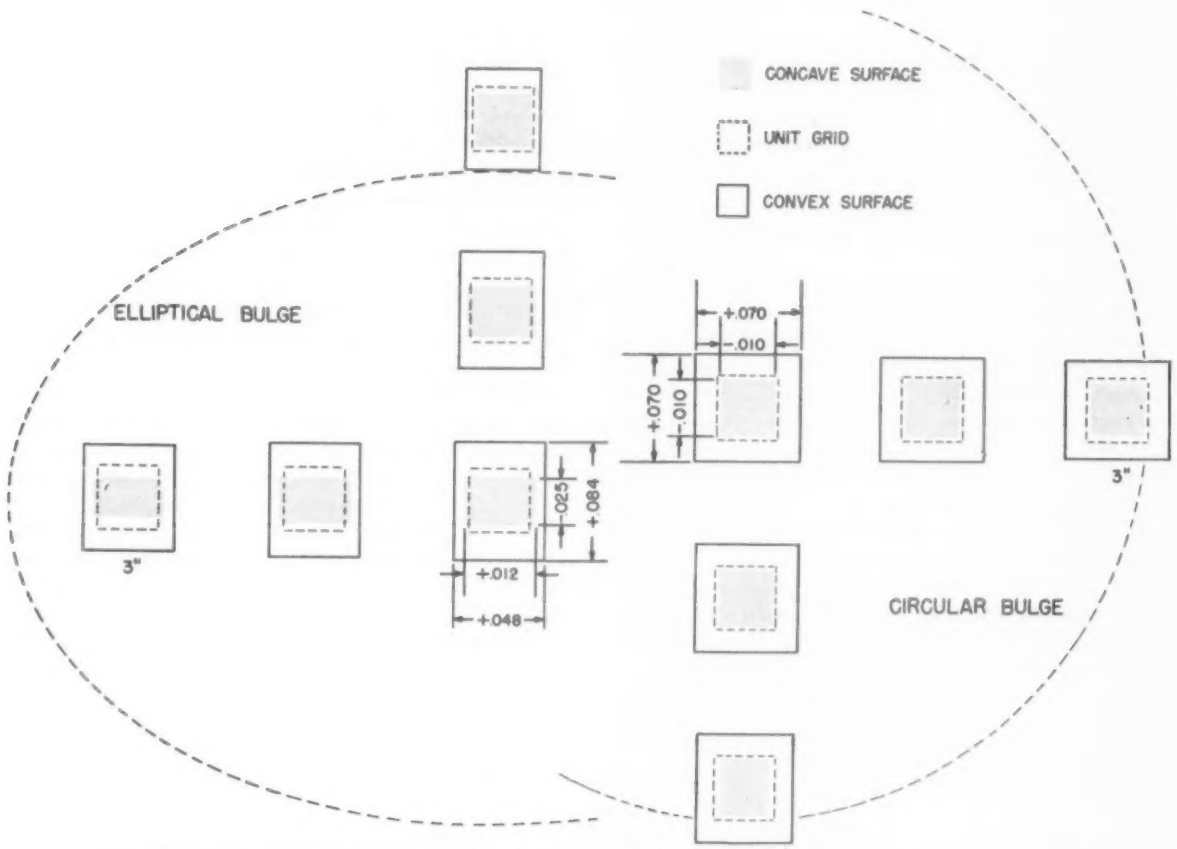
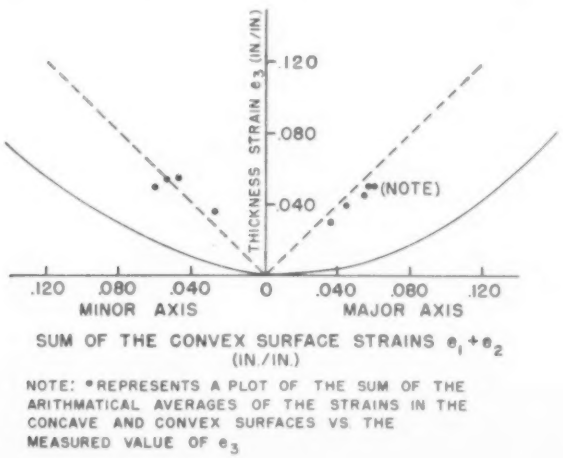


Fig. 6 Relative straining in the concave and convex surfaces. In the early stages of bulging the concave surface is in compression

tion of the strains in the concave and convex surfaces of circular and elliptical bulges at low levels of deformation.

As the result of bending, the sum of the biaxial surface components are not equal to the thickness strain (in the bulging of diaphragms constancy of volume in plastic flow requires that $e_1 + e_2 = e_3$). Figure 7 shows the relationship between thickness strain measured by micrometer caliper and the sum of the surface strains by photogrid. It is to be noted that at low levels of strain the sum of the surface strains increased much more rapidly than the thickness strain, whereas at higher levels of deformation their rates became more nearly equal. Using an arithmatical average of the


THICKNESS STRAIN e_3 (IN./IN.)
.120
.080
.040
*(NOTE)
.120 .080 .040 0 .040 .080 .120
MINOR AXIS
MAJOR AXIS
SUM OF THE CONVEX SURFACE STRAINS $e_1 + e_2$ (IN./IN.)
NOTE: *REPRESENTS A PLOT OF THE SUM OF THE ARITHMATICAL AVERAGES OF THE STRAINS IN THE CONCAVE AND CONVEX SURFACES VS. THE MEASURED VALUE OF e_3

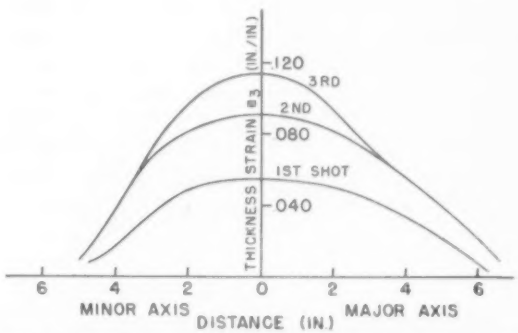


Fig. 7 Distribution of thickness strain and its relation to surface strain

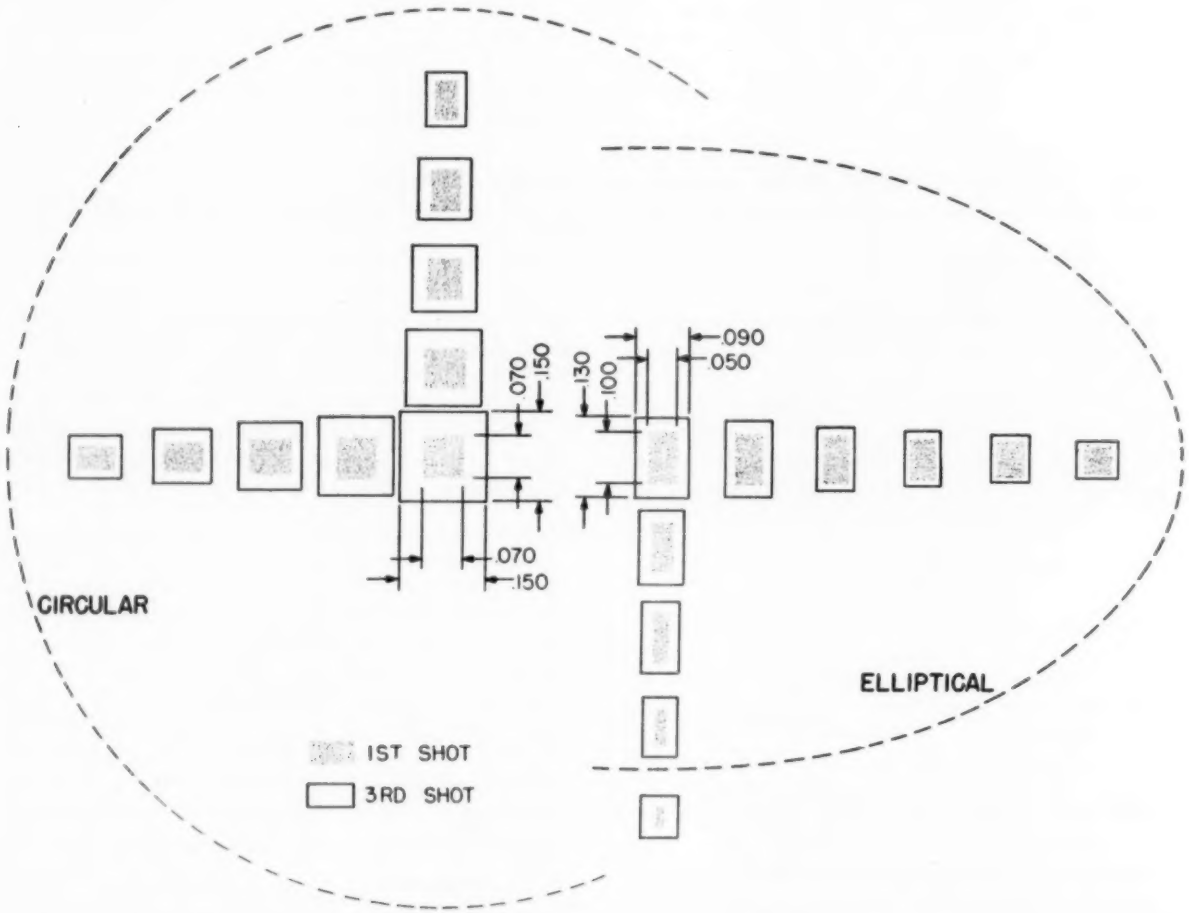
In the early stages of bulging, the strain in the convex surface of the bulge develops much more rapidly than the thickness strain.

strains in the concave and convex surfaces to provide a nominal value of bulge strain at any given section (vector at mid-thickness—assuming a linear distribution of plastic flow), the sum of the average ϵ_1 and ϵ_2 strains may be plotted against the measured value of ϵ_3. A reasonably good equality is indicated (Fig. 7).

DEVELOPMENT OF INSTABILITY

It has been pointed out that at a certain critical level of deformation a condition of instability may be expected to develop. When unstable flow occurs, straining becomes localized, the geometry of the test specimen changes, and the stress in that portion of the specimen undergoing plastic flow is no longer under control. For example, in the formation of an elliptical bulge, the strain ratio at the crown of the bulge changes continuously gradually approaching one. Thus, the limiting condition in an elliptical bulge is that stage of deformation at which there is an excessive alteration in the strain ratio; i.e., loss of control over the stress state. In the case of the circular bulge, the strain state is constant but instability is manifest by localization of flow and an attending loss of pole area (an important requirement of the weld bulge test is that uniform deformation occur over an area sufficiently great to encompas weld deposit, heat-affected zone and a portion of the unaffected parent plate).

Figure 8 illustrates schematically the distribution and progression of flow in a circular and elliptical bulge each formed by the same increment loading procedure (a succession of three 4-lb shots at 12-, 18- and 24-in. standoff). Note that in the case of the elliptical bulge, the rates of increase of ϵ_1 and ϵ_2 in the pole region were not equal, ϵ_2 increased more rapidly than ϵ_1; consequently, as straining progressed the strain state approached balanced biaxial tension. Localization of flow in the circular bulge resulted in a severe strain gradient. The marked difference in the progression of strain between the two geometries of bulge may be seen by noting that the increase in strain was only 60% in the elliptical bulge as compared to 114% in the circular bulge with the same increment loading. Localization of flow in the elliptical bulge was found to be best illustrated by thickness strain ϵ_3. The increase in ϵ_3 from first to second shot was quite uniform over most of the



DISTRIBUTION AND PROGRESSION OF SURFACE STRAIN ON REPEATED LOADING

Fig. 8 Distribution and progression of surface strain on repeated loading. Instability and localization of flow are indicated

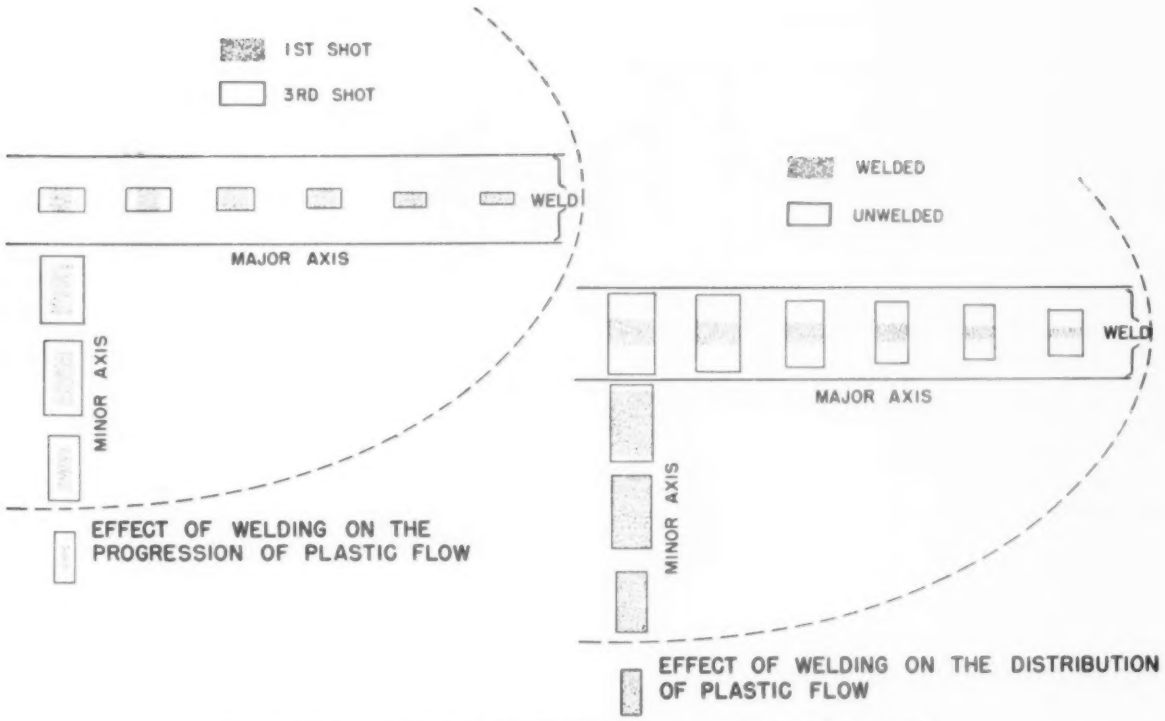


Fig. 9 Effect of welding on the distribution and progression of plastic flow

Comparing welded and unwelded, note the marked deconcentration of transweld strain and the equality of strain in the weld-longitudinal direction; comparing first and third shots welded, note the resistance of the weld metal to flow in the transweld direction.

bulge area; whereas the increase from second to third shot was largely confined to the pole region—pointing to the formation of a secondary bulge (Fig. 7). Note also that in the plot of thickness strain versus depth of bulge (Fig. 3) the slope of the curve increased at a gradually increasing rate up to about 10% reduction-in-thickness after which the slope increased at a more rapid rate indicating that for a small increase in depth of bulge, a large reduction in thickness occurred (analogous to necking in the tensile test).

MODIFICATION OF STRAIN STATE DUE TO THE PRESENCE OF WELDS

The presence of a weld may greatly alter both the distribution and progression of plastic flow in the bulge. In Fig. 9 the effects are schematically illustrated for the case of an elliptical bulge containing a weld of flow strength greatly overmatching that of the parent plate. A comparison between the strain distributions in the weld and at positions somewhat removed from the weld disclosed that a marked reduction of strain (hereinafter called a strain deconcentration) occurred in the transweld direction at locations in the weld and near-weld regions. In the initial stage of deformation the 1:2 strain state of the unwelded bulge was modified to 1:1 by the transweld strain deconcentration. Moreover, as straining proceeded (from first to second to third shot) the magnitude of the transweld component was essentially unchanged; whereas, the weld-longitudinal component increased until on the third shot the strain was 2:1—a complete reversal of the 1:2 strain ratio in the unwelded bulge.

Figure 10 illustrates the strain anisotropy of two welds of widely different flow strengths in circular bulges of HTS. When the flow strength of the weld exceeded that of the base metal (E12016-HTS) a transweld strain deconcentration occurred in the weld and near-weld regions. When the flow strength of the weld was less than that of the base metal (E6010-HTS) a concentration of strain developed in the weld causing premature failure in the weld metal. The relatively low resistance to flow of the E6010 weld in HTS aggrevated the natural tendency for localization of flow in the circular bulge. A comparison of the distribution and progression of thickness strain in various combinations of weld and base metal flow strengths confirms this observation. From Fig. 4 note that for a given increment of load (each shot consisting of 4 lb of explosive at 15-in. standoff) the flow strengths of weld and base metal determined the energy (number of shots) that could be delivered to the plate before instability developed. As a general "rule of thumb" 10% reduction of thickness in the pole region is the limit of useful strain in the explosion bulge test.

A COMPARISON OF CIRCULAR AND ELLIPTICAL TRANSITIONS

In order to provide a comparison between the fracture

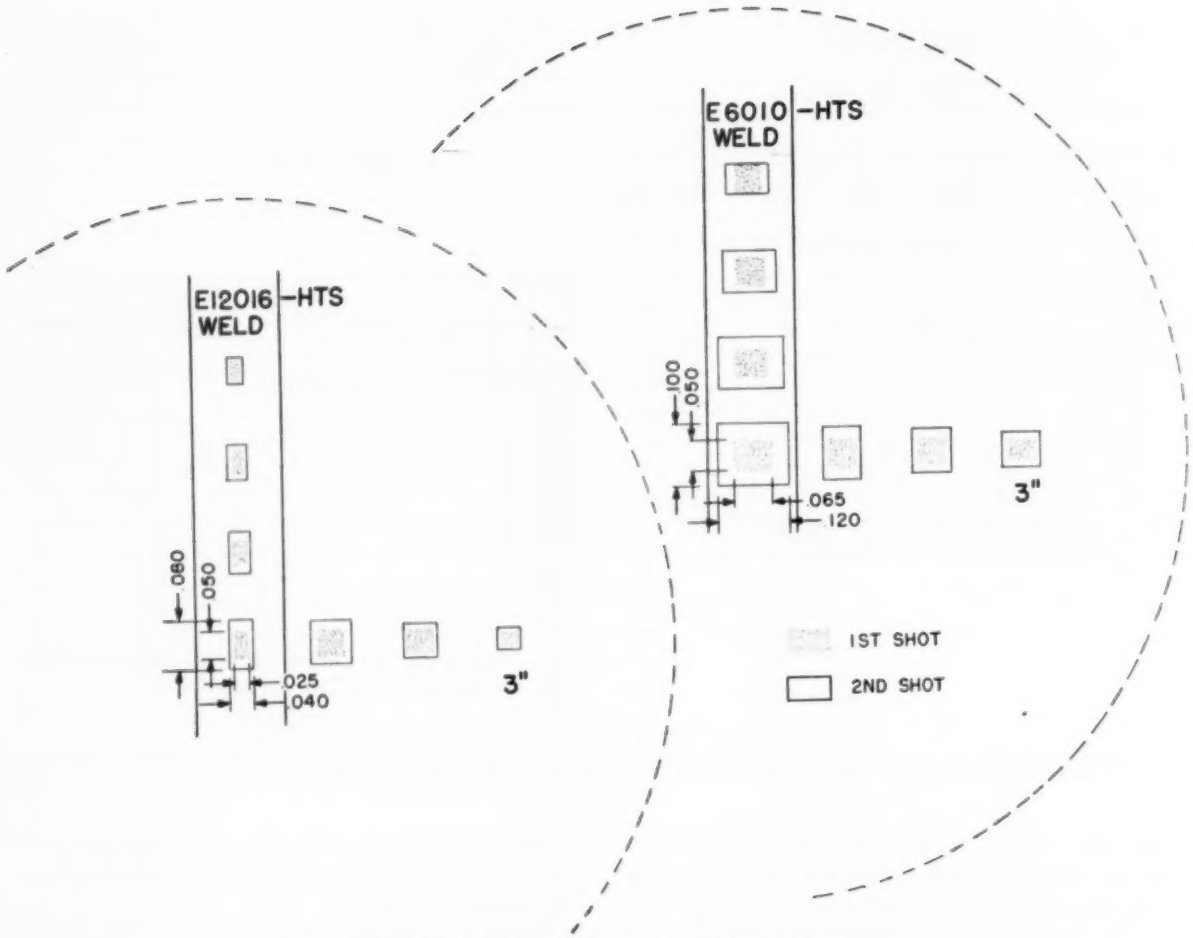


Fig. 10 Distribution of strain in welds of different flow strengths

With the flow strength of weld metal greater than that of the base metal, a strain deconcentration develops in the transweld direction; with weld flow strength less than that of the base metal, a strain concentration occurs in the joint.

performance of circular and elliptical bulges, weldments were prepared using E6010 and E12016 weld metals and the same mild steel base metal as tested previously over the circular die.[2] Two elliptical bulge transitions were determined for each weld metal—one with the weld on the major axis and one with the weld on the minor axis.

In the case of the E6010-MS combination (Fig. 11) no difference was observed between the two orientations of weld in the elliptical bulge. The temperature corresponding to the lower side of the transition range was the same for circular and elliptical bulging. The upper transition, however, was approximately 25° F higher using the elliptical die. The fractures initiated in the E6010 weld metal and generally propagated in the transweld direction. An occasional weld-longitudinal fracture occurred with the weld on the major axis.

The E12016-MS combination (Fig. 12), on the other hand, indicated a decided difference between the two orientations of weld. With the weld on the major axis the transition range was broad, extending from approximately −110 to −50° F (or higher). Fractures initiated in the base metal at distances of $^1/_2$ to $3^1/_2$ in. from the centerline weld. With the weld on the minor axis a narrow transition was indicated at approximately −80° F. Of nine fractures examined, four initiated at weld metal porosity and five initiated in the HAZ at a distance of approximately $^3/_4$ in. from the weld centerline. Three of the four weld metal failures should be discounted in analyzing the effect of bulge geometry on transition because they were X-ray rejects (the weldments containing heavy porosity were tested at dry-ice temperature to see whether HAZ failures would occur in spite of the porosity). A comparison between the transitions obtained by circular and elliptical bulging indicated the upper transition to be higher by the elliptical bulge. The difference between the circular and elliptical bulge was greatest with the weld on the major axis (approximately 50° F higher by the elliptical bulge); with the weld on the minor axis, the strain state more nearly matched that of the circular bulge and the difference was only 25° F. Insufficient data are available for comment on the lower transition, although the indication is that at a near-zero level of deformation

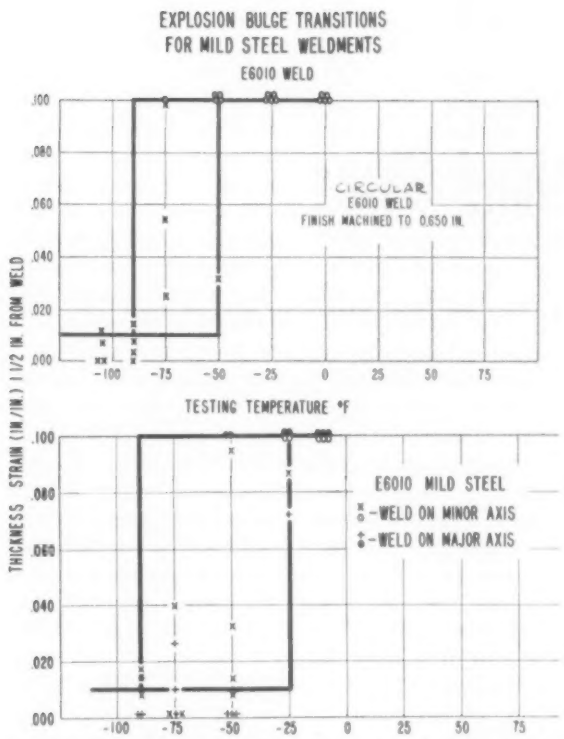


Fig. 11 Transitions from ductile to brittle behavior in circular versus elliptical bulges—E 6010 weld metal in mild steel

Little or no difference is indicated between the two geometries of bulge at the temperature producing extreme brittleness (failure at a near-zero level of strain).

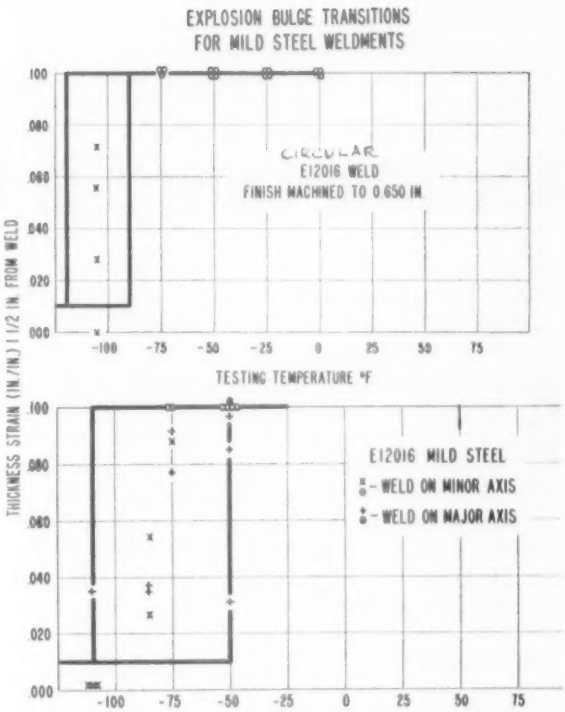


Fig. 12 Transitions from ductile to brittle behavior in circular versus elliptical bulges—E 12016 weld metal in mild steel

Note the difference in performance between the two orientations of weld in the elliptical bulge.

there is no appreciable difference between the circular and elliptical bulge performance.

It appears that no particular advantage is gained by the use of the elliptical bulge. Anisotropy inherent to weldments results in unbalanced stress and strain in the weld and near-weld region of circular bulges. Thus, an unbalanced load imposed by means of elliptical geometry can accomplish little more than modify the unbalance introduced by the anisotropy of the weld region. The shift in the upper limit of the transition range is believed to be the result of this modification of the strain state. The lower limit, on the other hand, which corresponds to fracture at or about the elastic limit, would not be expected to be influenced by a modification of biaxial load field.

ACKNOWLEDGMENTS

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References

1. Troxell, G. E., Parker, E. R., Davis, H. E., and Boodberg, A., "The Effect of Temperature and Welding Conditions on the Strength of Large Welded Tubes," THE WELDING JOURNAL, **27** (2), Research Suppl., 35-s to 48-s (1948).
2. Hartbower, C. E., and Pellini, W. S., "Explosion Bulge Test Studies of the Deformation of Weldments," *Ibid.*, **30** (6), Research Suppl., 307-s to 318-s (1951).
3. Hartbower, C. E., and Pellini, W. S., "Investigation of Factors Which Determine the Performance of Weldments," *Ibid.*, **30** (10), Research Suppl., 499-s to 511-s (1951).
4. Lankford, W. T., "Hydraulic Bulge Testing of Sheet Metals," ASTM Special Tech. Pub. No. 87 entitled "Symposium on Deformation of Metals as Related to Forming and Service (1948).
5. Lankford, W. T., and Saibel, E., "Some Problems in Unstable Plastic Flow Under Biaxial Tension," *AIME Trans.*, Inst. Metals Div., **171**, 562 (1947).

Structural Failures in Welded Ships

An investigation of the causes of structural failures

RESEARCH efforts of the Metallurgy and Mechanics Divisions of the National Bureau of Standards undertaken at the request of the Ship Structure Committee have provided additional evidence on the major causes of structural failures in welded merchant ships—in particular, the critical role of certain properties of steel which, in the past, have not been recognized in specification requirements. Much of this knowledge and pertinent design data obtained at NBS and other laboratories has already been incorporated into ship construction specifications in an effort to eliminate future failures of this kind. Such failures have cost the nation almost 50 million dollars in the past nine years, and there have also been costly failures in other structures such as bridges, storage tanks and pressure vessels.

In April 1943, the Secretary of the Navy established a Board to Investigate the Design and Methods of Construction of Welded Steel Merchant Vessels. That Board and its successor, the Ship Structure Committee, conducted extensive technical and statistical studies of the casualties, and initiated research projects in several laboratories for the study of some of the factors involved. The Metallurgy Division of the National Bureau of Standards, which had already assisted in investigations of some of the earlier failures, was assigned to the investigation of the plates removed from the fractured ships. When sufficient and suitable material was available, the laboratory investigation included examination of the fracture and of welds, microscopic examination, chemical analyses of the plates, Charpy V-notched bar tests over a range of temperatures, and tension tests.

To coordinate the results of the laboratory investigations with service experience, information was obtained from the Coast Guard and other cooperating agencies regarding the circumstances of the casualties, structural features of the ships involved, location and extent of the fractures and other pertinent details.

The NBS Mechanics Division became active in the investigation of ship failures in 1947 when tensile tests were begun on a series of large specimens representing some of the hull structural details in which fractures had originated. These tests were designed to determine the relative worth of certain structural details in service. Later, practical improvements of some designs were investigated.

There are three basic factors involved in the prevention of failures of welded structures. First, the material—mostly steel plates and weld metal—should uniformly possess the properties anticipated by the designer, and these properties should not be affected adversely by the effects of fabricating operations or operating conditions. Second, the design should produce an economically sound structure capable of performing its required functions under all operating conditions. Third, workmanship or fabrication—the work of the fitters, welders, supervisors and inspectors—must carry out the ideas of the designer, and must produce joints of the strength which he intended. The work of the Metallurgy Division has been concerned primarily with the first of these factors, that of the Mechanics Division with the second.

MATERIALS

Tension tests indicated that the plates which had fractured in service would meet the specification requirements under which they were purchased. This type of steel, in the usual tensile test, elongates under load more than 20% in 8 in., and the reduction of cross-sectional area is about 50%. This indicates that the material is capable of considerable plastic deformation before it will fracture.

The fractures in the ships, however, showed very little evidence of plastic deformation, or ductility. Nearly all of these fractures were of a brittle type, characterized by a break nearly perpendicular to the plate surfaces and a coarse granular or crystalline appearance. The reduction of thickness at the fracture edge was very small, usually less than 2 or 3%, and the paint or scale on the plate surfaces was not cracked, even very near the fracture. This showed that the fractures had propagated with very little plastic deformation of the steel. Since energy, or the capacity for doing work, is proportional to the integral of stress (or force) times deformation (or distance through which the force acts), it is evident that much less energy was absorbed in the propagation of these fractures than in normal ductile fractures of the material.

The lack of ductility and the brittle nature of these fractures indicated that when the steel was incorporated in the structure of the ship, the mechanism of fracture, or the mechanical properties of the steel, were not the

same as when determined by the usual tensile test using relatively small specimens. This phenomenon is similar to that observed in tests of notched specimens in tension or bending, particularly at low temperatures. The similarity is also evident in the facts that the fractures in the ships occurred more frequently at the lower temperatures, and that the starting points of the fractures could be traced, invariably, to geometrical or metallurgical notches resulting from structural or design details, fabrication processes, or welding defects. This phenomenon, called notch brittleness, is not peculiar to ship plate alone, nor is it confined to metals. The scoring of glass for cutting and the notching of cellophane wrappers are familiar examples in which notch sensitivity is utilized to control the location or direction of a tear or fracture.

The herringbone markings or chevrons in the fracture were found to be characteristic of the brittle type fractures in most of the ship plates examined. This type of fracture was observed and reproduced at NBS about fifteen years ago, in tests conducted to determine the source of a brittle failure of an aircraft part. These tests showed that a brittle failure may be produced in a normally ductile metal by applying a tensile stress to a notched plate specimen, and also established the fact that the chevrons always point back toward the origin of the fracture. This makes it possible to locate sources of the fractures in the ships.

The source of a number of the fractures which were examined was found to be in the shell plate at the end of a longitudinal stiffener, within a few inches of a transverse bulkhead. The longitudinal, which is welded to the shell plating, is interrupted for a space of about six inches to allow for insertion of the transverse bulkhead, to which it is connected, at a point several inches from the shell plating, by gusset plates on the flanges of the longitudinal. This condition, which constituted a structural notch at the abrupt end of the longitudinal stiffener, was responsible for a number of failures in tankers.

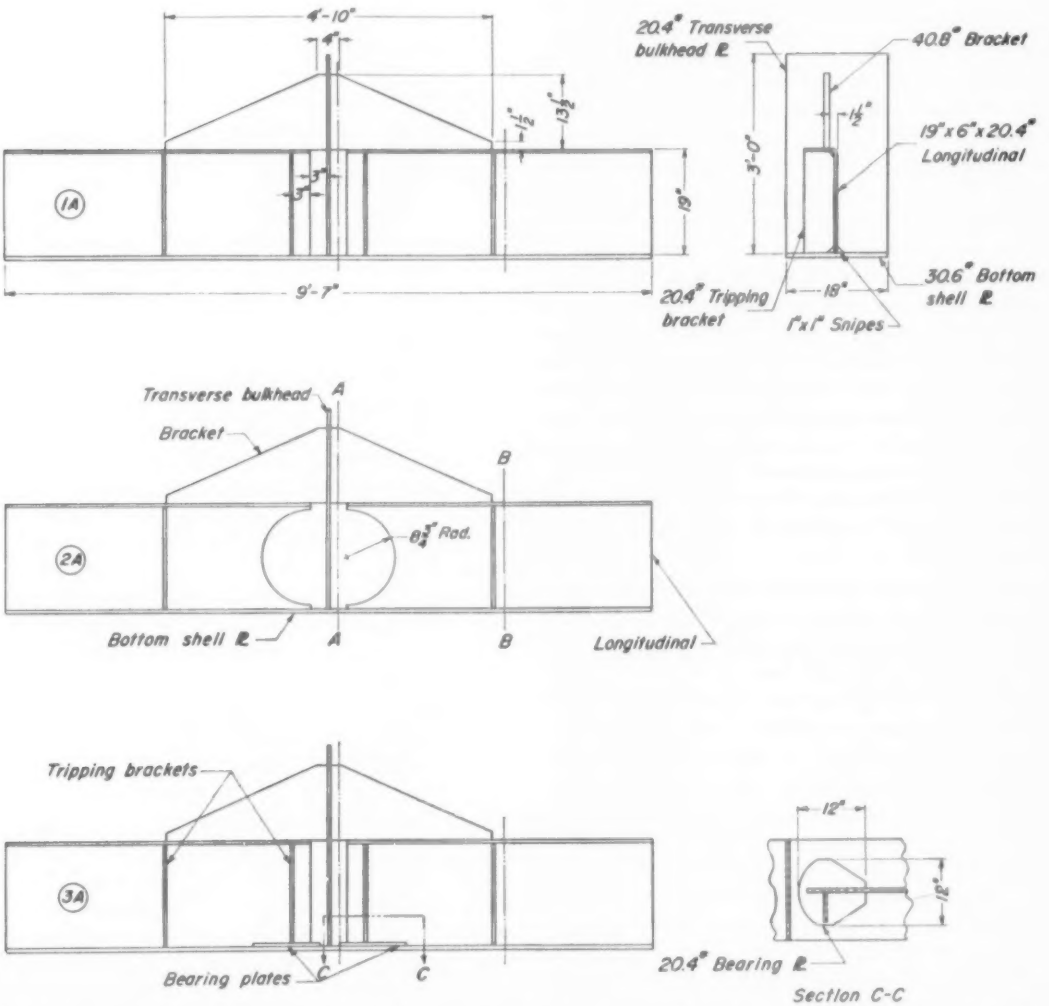

Fig. 1 Details of interrupted longitudinal specimens—Specimen 1A is the original basic design. Specimen 2A, material is removed to make a less rigid design. Specimen 3A, material is added to reduce stress concentrations

This design detail is one of those being investigated by the NBS Mechanics Division.

The importance of notch brittleness of the steel as a factor in the failures was recognized early in the investigation, and impact tests, using V-notch Charpy specimens, were included in the examinations of the fractured plates in order to evaluate this factor. In this test the specimen is supported at the ends and broken by the blow of a pendulum on the face opposite the notch. Tests are made at a series of temperatures and the energy absorbed in the fracturing process is measured.

In impact tests of notched specimens, most steels are notch tough at higher temperatures, but as the temperature is lowered they become, suddenly or gradually, more brittle, and the energy required to produce fracture is reduced to a small fraction of that which can be absorbed at higher temperatures. The range of temperatures within which these changes take place, for a given steel, is called the transition range of that steel. Usually, for convenience, a specific point in this range is referred to as the transition temperature, defined by such criteria as the temperature at which the energy absorbed is 50% of the maximum, or the temperature at which the energy absorption is at a definite level, say 15 ft-lb for a V-notch Charpy specimen. The transition temperature is one measure of the notch brittleness of the steel.

After impact tests had been completed on only a few plates, it was observed that the plates in which the ship fractures originated showed higher transition temperatures than plates which did not contain a fracture source. Therefore, the fractured plates for which definite information was available were classified into three categories: those which contained a fracture source (in the ship failures), those which were fractured through and those which contained the end of a fracture. The plates were also classified in groups on the basis of plate thickness, to permit comparisons of data for similar material, and plates which were not strictly "hull plates of welded ships fractured under normal operating conditions" were placed in a separate miscellaneous group.

Table 1 contains the essential data taken from curves showing the frequency distributions of 15 ft-lb transition temperatures of the plates in the fracture source, fracture through and fracture end categories. The distribution of the fracture through plates approximated the normal probability curve. The fracture source plates were found to have a higher average transition temperature, while the relative proportion of fracture source to fracture through plates in each interval increased with increasing transition temperature. The latter indicates that the probability of a fracture starting in a plate, under the conditions existing in a structure such as a ship, increases markedly with increasing notch sensitivity of the plate, as determined by the 15 ft-lb transition temperature of V-notch Charpy specimens.

The frequency distribution curves also showed that the plates with high transition temperatures, in which fractures are most likely to originate, represent the relatively few plates whose notch sensitivity falls in the tail of the probability curve for steels of the quality used when these ships were built. This suggests two possible remedies: (1) Improvement of the average quality of the steel with respect to notch sensitivity. (In effect, moving the entire probability curve in the direction of increased notch toughness, so that a much smaller proportion of the plates in the tail of the curve would fall beyond acceptable limits of notch sensitivity.) (2) Determination of the notch sensitivity of every heat of

Table 1—Comparison of Average Transition Temperatures of All Plates in the Source, Through and End Categories

Nature of fracture	*No. of plates*	*Avg. 15 ft-lb trans. temp., ° F*	*Standard deviation, ° F*
Source	30	102.5	25.0
Through	45	65.7	17.5
End	38	56.3	20.1

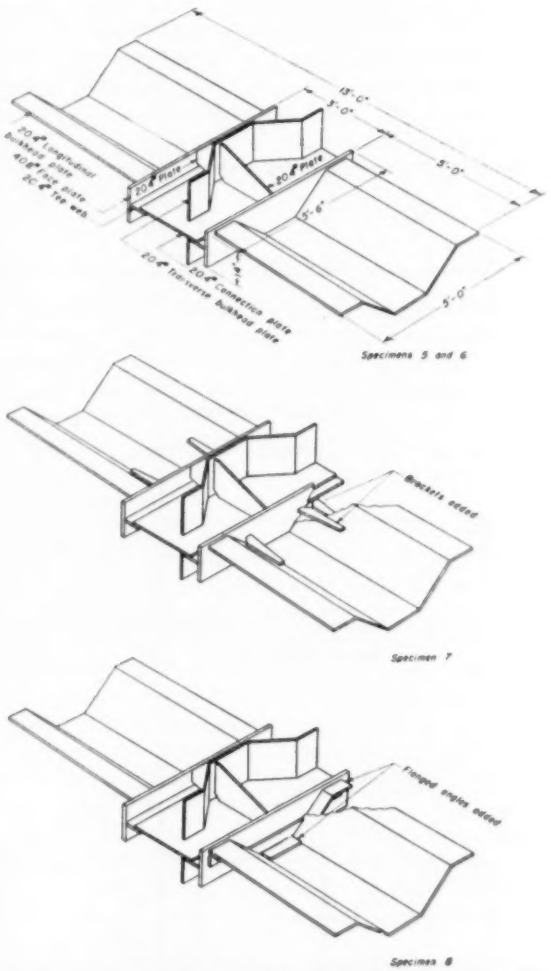

Fig. 2 Details of bulkhead intersection specimens. Specimens 5 and 6 are of the original design. Specimens 7, brackets added to reduce stress concentrations. Specimen 8, formed angles added to reduce stress concentrations

steel by inspection tests, and rejection of all heats which fail to meet suitable prescribed standards. (In effect, "cutting off the tail" of the probability curve.)

In order to provide information pertinent to (1) above, the test results have been compared with the chemical composition of the steels and an extensive statistical analysis made to determine the effects of individual elements. This analysis has showed that the notch sensitivity is increased with increasing amounts of carbon and phosphorus, and decreased with finer grain size and with increasing amounts of silicon and manganese, within the range of the chemical compositions of the ship plates studied.

STRUCTURAL DETAILS

A welded tanker afloat at sea may be considered as a hollow beam of great depth upon which a system of complex and variable forces operate. The weight and proportions of the ship, the type and distribution of the cargo, the type of propulsion and practical fabrication procedures are variables subject to control. The uncontrollable forces of sea and wind can presently only be estimated. The designer's problem is further complicated by the fact that the steel of which a welded ship is made has pronounced changes in mechanical properties within the range of operating temperatures.

Practical solutions of the problems of designing and constructing a steel ship result in various and numerous structural discontinuities, especially at the connections of intersecting members and plates. Such discontinuities often constitute a "mechanical notch" and nearly always produce some concentration of stress in the area of the discontinuity. Since the load-carrying capacity of the structure or ship as a whole, and its ability to absorb energy of deformation, may be seriously reduced by excessive stress concentration, the design details at discontinuities are especially important.

The T2 all-welded tanker was designed and developed during World War II to take advantage of ship plate steel procurable in large quantities and to minimize time-consuming fitting and joining processes. A large number of these ships were constructed and served their intended purpose. However, to insure and prolong the life of these ships, modification of certain structural details had been made with undetermined results. The prime purpose of the investigation in the Mechanics Division of NBS was to evaluate the load carrying and energy absorption ability of certain original structural designs and a few practical modifications of these designs.

Observations on the ships and examinations of fracture sources indicated that fractures occurred in those parts of the ship sustaining large tensile loads. In view of this and the impracticability of simulating exact shipboard loading conditions, tensile tests of the detail in question were made in the laboratory. Specimens were similar to ship construction as far as material, plate thickness and welding procedures were concerned. Stress studies were made at room temperature; tests in which the applied stresses were below the elastic limit of the material. Since a large number of the fractures occurred in cold water, most of the specimens were tested to failure near 0° F. Some longitudinal specimens were tested at various other temperatures to obtain an indication of the effect of temperature on the mode of fracture.

Fig. 3 Interrupted longitudinal Specimen 10A immediately after fracture. Maximum load sustained: 960,000 lb

A source of many of the serious ship failures was at the intersection of a bottom longitudinal and a transverse bulkhead, a design detail which is repeated more than one hundred times in the structure of a tanker. Three general designs of this detail were investigated by the NBS Mechanics Division. Some results of these tests, grouped by specimen type, are given in Table 2. Specimen 1A represents the original design used in T2 tankers and is relatively rigid. The 2A type specimen is a more flexible structure due to the removal of material by a semicircular cutout. Specimen 3A retains the rigidity of 1A but reduces the stress concentration in the bottom plate by increasing the plate thickness at the point of highest stress. Minor modifications of these designs were made and tested when they appeared practical.

Four bulkhead intersection specimens of three general designs were investigated; results are shown in Table 3. Specimens 5 and 6, the original design, were dimensionally similar but varied in welding technique. Specimens 7 and 8 represented two methods used to re-

Table 2—Results of Interrupted Longitudinal Tests

Specimen No.	*Test temperature, ° F*	*Maximum load, lb*	*Energy to fracture, ft-lb*
1	0	750,000	30,700
1A	−15	843,000	28,300
1A2	40	1,083,000	102,900*
1A3	20	1,015,000	62,700
1A4	−5	905,000	36,300
1A5	5	1,052,000	94,100
10A	0	960,000	64,300
11A	−5	912,000	36,000
2	0	774,000	46,100
2A	0	993,000	121,600*
2A2	0	918,000	141,000*
2A3	−20	826,000	11,300
3	0	843,000	49,700
3A	10	1,091,000	126,300
12A	−5	1,047,000	65,900*

* Broke outside of intersection.

Fig. 4 Taking data during a room temperature test of an interrupted longitudinal specimen. Tensile capacity of this machine: 1,150,000 lb

duce stress concentrations by adding material to the basic design.

The brittle nature of shipboard fractures was duplicated in the laboratory tensile tests of interrupted longitudinal and bulkhead intersection specimens at low temperature.

Results of NBS tests indicate that the load-carrying ability of the interrupted longitudinal designs does not vary greatly and is probably adequate for the purpose intended. In view of this, the structure which is capable of greater deformation and is therefore able to absorb a relatively large amount of energy before fracture is most suitable for this type service. The design represented by specimen 2A appears somewhat superior in this respect. In some modifications of T2 tankers, designs similar to specimen 2A have been used to replace the original longitudinals represented by specimen 1A. Results of the tests of bulkhead intersection specimens indicate that the addition of material near regions of high stress is beneficial.

For further technical details see References 1–3.

Table 3—Results of Bulkhead Intersection Tests

Specimen No.	*Maximum load, lb*	*Energy to fracture, ft-lb*
5	860,000	11,400*
6	774,000	61,800†
7	944,000	45,200†
8	1,129,000	68,800

* Partial fracture.
† Fracture began in defective weld.

References

1. Williams, M. L., "Brittle Fracture in Ship Plates." Proc. NBS Semicentennial Symposium on Mechanical Properties of Metals at Low Temperatures. NBS Circular 520 ($1.50 from Superintendent of Documents, Government Printing Office, Washington 25, D. C.).
2. Campbell, W. R., "Stress Studies of Ship Structure Specimens," The Welding Journal, **30,** (2), Research Suppl. 68-s to 75-s (1951).
3. Campbell, W. R., Irwin, L. K., and Duncan, R. C., "Stress Studies of Welded Bulkhead Intersections." *Ibid.*, **31** (2), Research Suppl. 68-s to 76-s (1952).

(*Continued from page 332-s*)

niques in American industry. Studies include welding of light metals, nonferrous metals and stainless steels; techniques of arc welding in inert gas, automatic welding and nondestructive testing; welding in structural work, bridge building, shipbuilding, heavy boilermaking and manufacture of apparatus for heavy industry, as well as processes used in the manufacture of commercial aircraft and railroad equipment. Robert H. Bratsch of MSA's Washington headquarters is project manager for this team. Stewart A. Robertson and H. E. Merchant, MSA Project Representatives, are accompanying Groups A and B, respectively.

Members of the two groups are:

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France: Jean Brillie, Manager, Liquid Air Welding Laboratory, Paris, and Henri Granjon, Chief Engineer, Institute of Welding, Paris.

The Netherlands: Willem Fredrik Happe, Director of Advisory Office for Gaswelding, Gascutting and Other Techniques in The Netherlands.

United Kingdom: Franz Koenigsberger, Lecturer, College of Technology, Manchester, and Charles Guy Parsloe, Secretary, The Institute of Welding, London.

Group B

Austria: Dr. Karl Kadlez, Chief, Material Testing and X-ray Laboratory of Boiler Plant, Simmering, Amhra Paukerwerke, Vienna, and A. Hans Melhardt, Chairman, Welding Committee, Austrian Standards Organization, Vienna.

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United Kingdom: Leonard Richard Creasy, Superintendent Structural Engineer, Ministry of Works, London; Leslie John Hancock, Technical Director, Hancock & Co. (Engineers) Ltd., Croydon; John Reginald Thomas, Group Welding Engineer, John Thompson Ltd., Ettingshall, and Henry Frederick Tremlett, Welding Metallurgist, United Steel Co. Ltd., Research and Development Department, Swinden Laboratories, Moorgate.

Copper in Type 347 Weld Metal

Recent reports of the suppression of sigma phase by copper additions are not substantiated by controlled experiments

by R. P. Wentworth

IN STAINLESS steel weld metal, cracking of the as-deposited weld may occur if proper attention is not paid to the composition balance of the alloy. One solution to the cracking problem is to introduce a slight amount of ferrite into the weld metal by adjusting the percentages of the ferrite-forming elements and the austenite-forming elements. The physical properties of partially ferritic stainless weld metal in the as-deposited and quench-annealed (1950° F) conditions are excellent; however, the ductility of the weld metal may be adversely affected by the transformation of the ferrite phase to the brittle sigma phase at elevated temperatures (1000–1600° F).

In weldments which will be subjected to elevated temperatures, either in postwelding heat treatments or in service, the embrittling effect of sigma must be considered.

It has been reported that the introduction of copper into the weld metal reduces to some extent the sigma phase embrittlement. The data supporting this claim appear to be rather meager and inconclusive. In a private communication from Rollason, Helmut Thielsch[1] presents data which tend to support the beneficial effects of copper. It is unfortunate, however that corresponding data for a similar copper-free composition are not available. A British publication[2] gives data on copper-bearing and copper-free stainless weld metal deposits containing columbium, but the data are quite inconclusive, since the copper-free deposit has considerably more ferrite (10–15%) than the copper-bearing deposit (about 5%).

If copper actually decreases the effect of sigma phase embrittlement, the mechanism could be one or a combination of the following three methods: (1) reduction of the original amount of ferrite present, (2) reduction of the rate of sigma transformation, (3) reduction of the inherent brittleness of the sigma particles. The first

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Table 2—Bend Ductility* of Free-Bend Specimens

No.	*F*,†%	*Cu*,†%	*As-welded*	*1200° F, 112 hr*	*1550° F, 112 hr*
1	0	0	48 A‡	38 B	41 A
2	0	2	42 A	38 B	41 B
3	0	4	38 B	28 C	34 B
4	4	0	43 A	42 B	39 A
5	4	2	41 B	30 C	36 B
6	4	4	37 B	34 B	35 B
7	9	0	37 A	31 B	32 B
8	9	2	37 B	30 C	25 C
9	9	4	34 A	25 C	25 C
10	4	0	38 B	32 C	37 C
11	4	2.5	44 B	33 C	34 C
12	9	0	47 A	32 B	30 C
13	9	2.5	48 B	19 D	21 D

* Percent elongation across weld face.
† Aim values.
‡ A, Pressed flat with little or no defects showing. B, Cracks appeared as specimens were being pressed flat. C, Cracks appeared after slight bending beyond 180 deg. D, Snapped at approximately 90-deg bend angle.

Table 1—Chemical Analysis Results

Test No.	*C*	*Mn*	*Si*	*S*	*P*	*Cr*	*Ni*	*Mo*	*Cu*	Calcd., % *F*	Obsd., % *F*
1	0.078	1.45	0.38	0.015	0.017	19.95	11.49	0.60	...	1	0/1
2	0.084	1.42	0.40	0.019	0.036	19.40	11.14	0.70	1.55	<1	0
3	0.066	1.37	0.39	0.016	0.022	18.96	10.76	0.76	3.91	2	0
4	0.080	1.40	0.37	0.012	0.023	20.10	10.21	0.62	...	5	5
5	0.080	1.40	0.37	0.017	0.025	19.65	10.18	0.63	1.76	4	4
6	0.076	1.42	0.37	0.016	0.024	19.38	9.98	0.72	3.54	4	0/1
7	0.072	1.50	0.38	0.008	0.028	20.10	8.92	0.86	...	9	10
8	0.078	1.45	0.45	0.009	0.032	19.37	8.66	0.88	1.78	8	7
9	0.068	1.45	0.42	0.007	0.026	19.59	9.31	0.92	3.74	8	6
10	0.076	1.52	0.96	0.013	0.010	19.42	10.21	0.88	0.14	7	6
11	0.075	1.54	0.94	0.010	0.008	19.59	9.60	0.94	2.90	8	5
12	0.060	1.59	0.87	0.008	0.011	20.40	9.13	0.86	0.06	12	10
13	0.060	1.49	0.91	0.008	0.005	19.67	8.58	0.97	3.31	10	9

method, of course, will result if copper is an austenite-forming element, but since it is desirable to maintain a certain ferrite level to insure freedom from as-welded cracking this is not a practical solution to the problem.

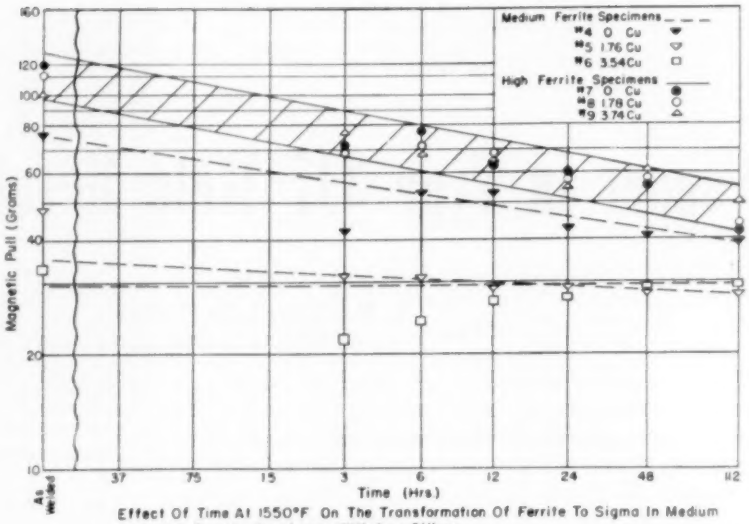
The second method would appear to be a reasonable possibility, and accordingly the rate of transformation of the ferrite in samples of varying compositions was studied in this laboratory. Hardness and magnetic tests were believed to be useful tools for this purpose. Direct evaluation of the third method is quite difficult; however, as a measure of the brittleness of the heat-treated weld metal, the free bend test was employed. Micro studies were also conducted on the heat-treated samples.

The results indicated that the presence of copper in Type 347 weld metal neither retarded the transformation of ferrite to sigma nor rendered it less brittle. In fact, at a high ferrite level copper appeared somewhat to increase the sigma embrittlement.

FERRITE AND COPPER LEVELS VARIED

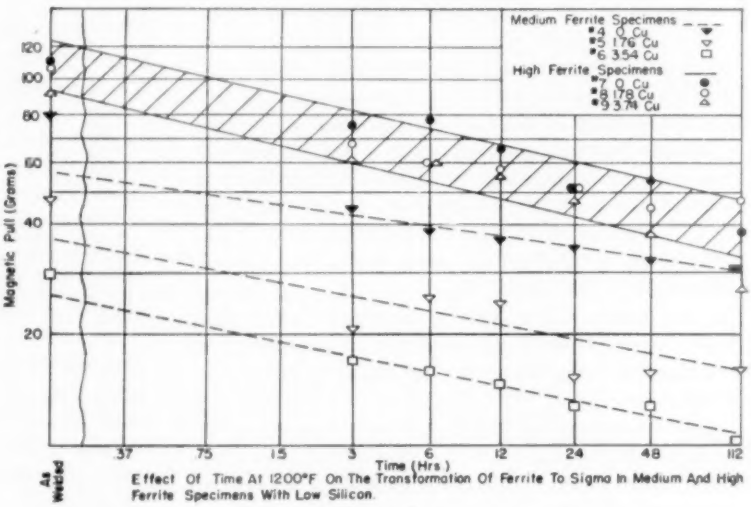
To find what effects varying amounts of copper and ferrite might have, nine electrodes were prepared which gave three levels of each of these two quantities. The following percentages were aimed for: copper, 2 and 4%; ferrite, 0, 4 and 9%. Later four more electrodes were made with a higher silicon content in an attempt to determine whether this factor would have a greater effect on weld metal ductility. Only two levels of ferrite and copper were studied this time, with the following aim percentages: Copper, 0 and 2.5%; ferrite, 4 and 9%.

Table 1 gives the nondilution weld pad analyses of the 13 compositions, the observed ferrite content determined from the as-welded microstructure, and the calculated ferrite contents determined from the Schaeffler[3] diagram for stainless weld metal in the as-welded condition. It can be seen that the calculated and observed ferrite percentages agree quite well, with the exception of some of the high copper samples. In these cases



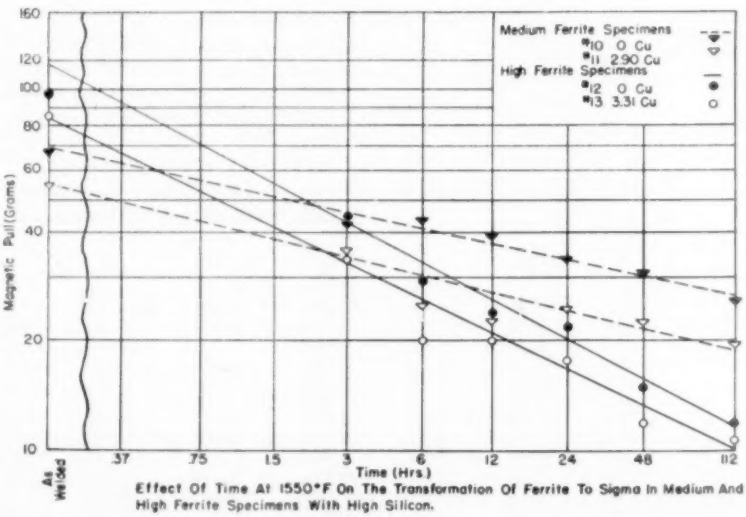
Effect Of Time At 1550°F On The Transformation Of Ferrite To Sigma In Medium And High Ferrite Specimens With Low Silicon

Figure 1



Effect Of Time At 1200°F On The Transformation Of Ferrite To Sigma In Medium And High Ferrite Specimens With Low Silicon.

Figure 2



Effect Of Time At 1550°F On The Transformation Of Ferrite To Sigma In Medium And High Ferrite Specimens With High Silicon.

Figure 3

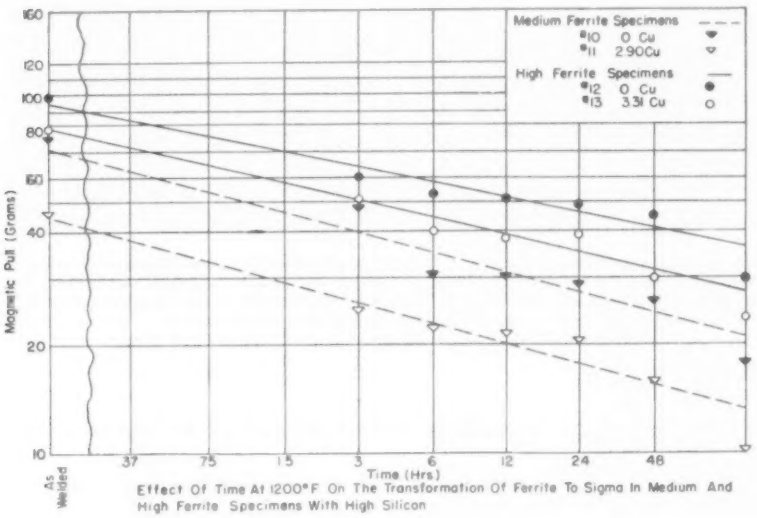
the observed values are somewhat lower than the calculated ones, indicating that copper is a mild austenite former, which confirms the opinion of most investigators.

COPPER DOES NOT RETARD RATE OF SIGMA FORMATION

Butt welds were prepared in $^3/_8$-in. Type 347 plate using these 13 compositions. Three free-bend specimens and three specimens for hardness and microexamination were taken from each of the plates. Sufficient numbers of specimens were thus available to permit investigation of two sigmatizing temperatures. The specimens were heat-treated for a total of 112 hr and magnetic and hardness readings were taken at specific intervals throughout the treatment. The magnetic measurements were conducted by suspending an Alnico magnet from a triple beam balance and determining the minimum force required to remove the magnet from the machined weld reinforcement of the bend test bar. The Rockwell 30T scale was used for the hardness measurements.

The rates of formation of sigma for the various deposits as measured by changes in magnetic strength are shown in Figs. 1 to 4. The sigma formation apparently had no significant effect on the hardness results, hence those data are not included in this report.

It appears that the transformation of ferrite to sigma is a straight line function on a log-log scale. The figures show that the transformation rates of the copper-free and copper-bearing high ferrite specimens are essentially parallel. Since the points for the high ferrite specimens with low silicon are so close (see Figs. 1 and 2), bands enclosing the points were drawn instead of lines. Comparison of Figs. 1 and 3 indicates that the effect of silicon is to increase the rate of transformation of the ferrite at 1550° F. The transformation rates of the high-silicon specimens at 1200° F (Fig. 4) on the other hand are similar to the low-silicon rates (Fig. 2).



Effect Of Time At 1200°F On The Transformation Of Ferrite To Sigma In Medium And High Ferrite Specimens With High Silicon

Figure 4

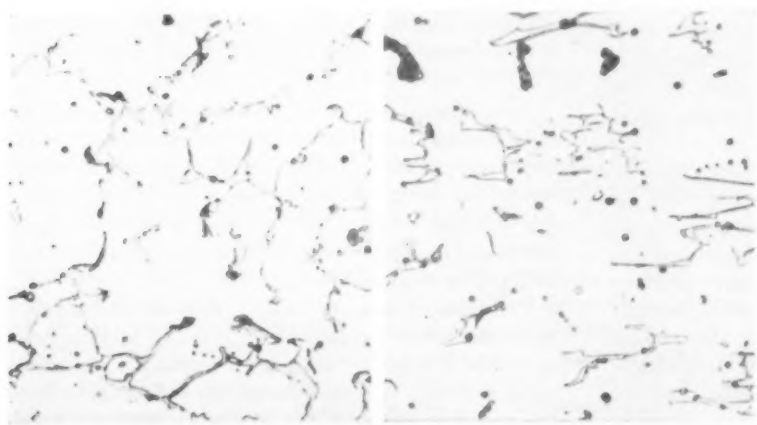


***Fig. 5** As-welded structures of low-silicon weld metal at high ferrite level. Specimen at left 0% copper; at right, 4% copper. Copper-free specimen was judged to contain about 10% ferrite, and 4%-copper specimen about 6% ferrite. Mag. 1000 ×. Etchant: 10% hydrochloral*

Even with high silicon, copper does not decrease the rate of formation of the sigma phase. It was thought possible that with a higher silicon content (and thus a potentially more brittle weld) the effects of the copper might be more evident. The transformation rates do not indicate this however.

Unfortunately, the magnetic readings of the various medium ferrite samples in the as-welded condition were not comparable, so any conclusion drawn as to the effect of copper would necessarily include the effect of the other variable—the as-welded ferrite content. It is believed that as the ferrite content is lowered the rate of transformation to sigma is decreased. This is presumably caused by a lower concentration of sigmatizing elements in the ferrite. Comparison of the high-silicon samples heat treated at 1550° F appears to support this theory. It may be observed from Fig. 3 that the slopes representing the medium ferrite specimens are such that the medium ferrite lines actually cross the high ferrite lines. As a result, the residual magnetism (after heat treatment) of the medium ferrite specimens is higher than that of the high-ferrite specimens.

The squares in Fig. 1 representing the medium-ferrite high-copper specimen would suggest that this specimen increases in magnetism.

The observed increase is quite small, although somewhat magnified on the log-log scale, and is believed to be caused by slight experimental errors.

COPPER DOES NOT APPEAR TO ALTER THE MICROSTRUCTURE OF AS-WELDED OR HEAT-TREATED METAL

Microexamination of the as-welded specimens did not reveal any additional phase as a result of the presence of copper. Figure 5 shows the as-welded structures of typical areas of weld metal at the high ferrite level, both with and without copper. The lesser amount of ferrite in the copper-bearing specimen is quite obvious.

Examination of the heat-treated specimens appeared to confirm the magnetic results, indicating that transformation to the sigma phase was almost complete in 112 hr. Figures 6 and 7 each compare the structure of the high-ferrite specimens after being heat treated at 1200 and 1550° F. The similarity between the copper-free and copper-bearing specimens may be noted. In these photomicrographs only the sigma phase has been heavily attacked: the sodium cyanide etchant was applied at a low current density for a short period of time.

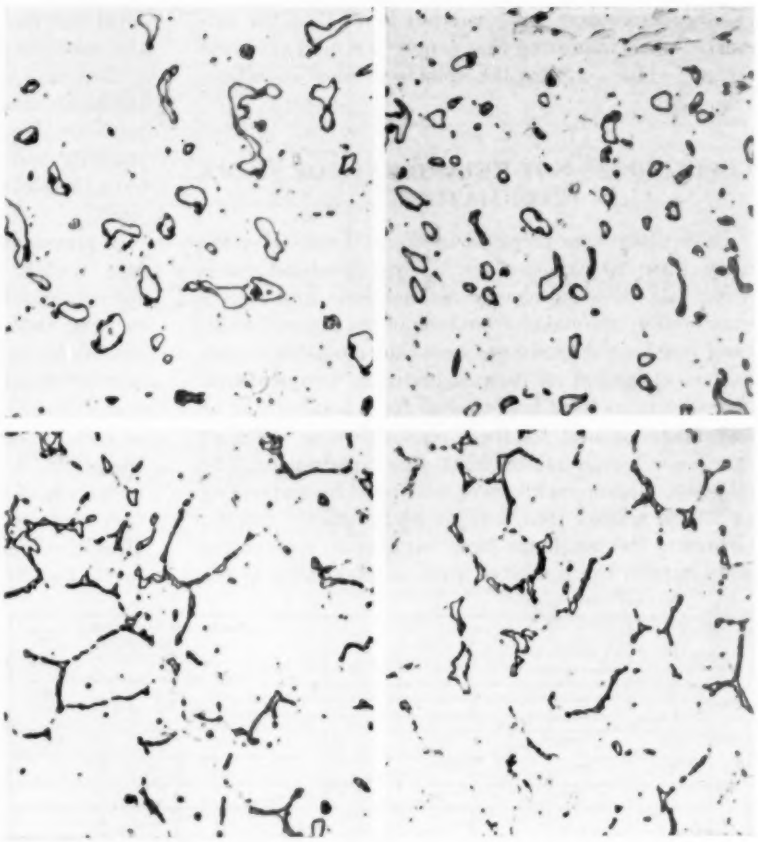


Fig. 6 Sigma phase structures of low-silicon high-ferrite weld metal specimens resulting from heat treating 112 hr at 1200 and 1550° F. Upper specimens, 0% copper; lower specimens, 4% copper. Note the lightly etched patches showing the presence of ferrite which has not transformed to sigma. Mag. 1000 ×. Etchant: 10% sodium cyanide at 0.4 amp/sq in. for 20 sec

BEND TESTS DO NOT INDICATE ANY REDUCED BRITTLENESS FROM THE PRESENCE OF COPPER

Even though the magnetic results indicated that copper did not retard the rate of sigma formation, it was hoped that there would be evidence that the copper had reduced the inherent brittleness of the sigma phase.

The bend test results in Table 2 show that ductility as revealed by the free bend tests is not improved by the addition of copper, either in low- or high-silicon weld metal. With traces or medium amounts of ferrite there is some indication that copper reduces slightly the ductility of the weld metal; with the high ferrite specimens, the adverse effect of the copper appears somewhat more definite, especially in the high-silicon specimens. It is interesting to note that the ductility of the 0% ferrite specimens (Nos. 1, 2 and 3) is satisfactory in all conditions. This is presumably the result of a favorable (high) carbon-to-silicon ratio.

FURTHER INVESTIGATION IS DESIRABLE

Even though these tests have failed to indicate any beneficial effects from copper, additional tests might reveal that copper is of some value in the sigma problem. Possibly longer times are necessary to reveal any favorable results. The data of Rollason as reported to Thielsch[1] show times of 300 and 5000 hr.

Also, it may be desirable to test the effect of prior heat treatments. It has been reported that a solution treatment (1900° F) prior to the sigmatizing treatments has resulted in an increase in the impact properties of copper-bearing weld metal, whereas little or no increase was observed with a similar composition of copper-free weld metal.

The question may be asked: How detrimental is a given amount of sigma phase? Has the ductility been seriously affected by the sigma formation, especially in those grades with medium amounts of ferrite? With the exception of Sample 5, which was heat treated at 1200° F, all of the medium ferrite specimens are well above the 30% minimum elongation requirements of the ASME Boiler Code. The amount of ferrite present

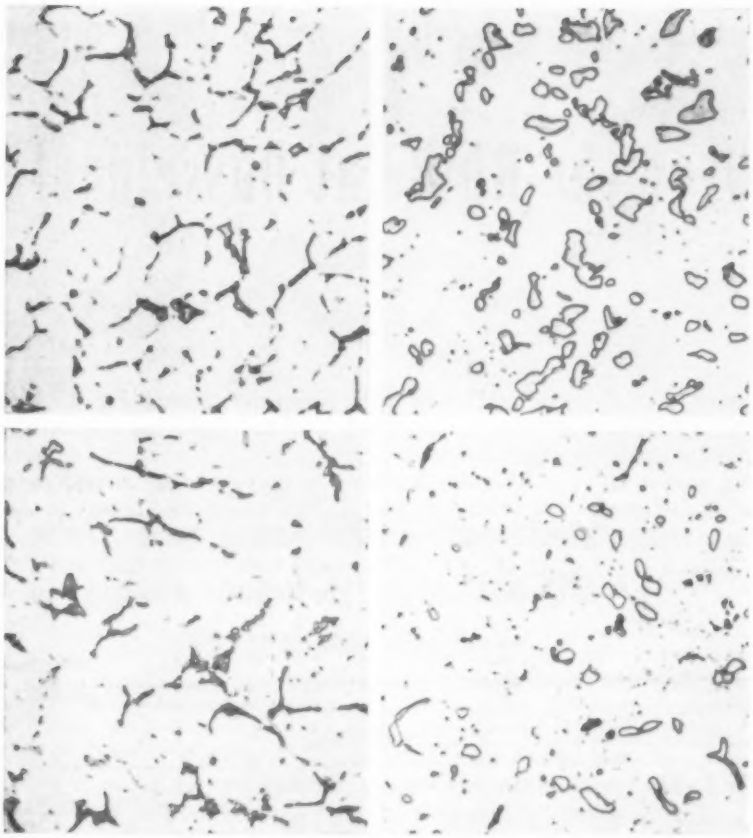


Fig. 7 Sigma phase structures of high-silicon high-ferrite weld metal specimens resulting from heat treatment at 1200 and 1500° F. Upper specimens, 0% copper; lower specimens, 2.5% copper. Mag. 1000 ×. Etchant: 10% sodium cyanide at 0.4 amp/sq in. for 20 sec

in all these medium ferrite specimens was quite sufficient to prevent weld metal cracking. Even the high ferrite specimens are satisfactory or nearly so in respect to this code requirement, except the high-silicon copper-bearing specimen.

Confirmation of these results by tests of large-scale weldments would seem to be very desirable.

Bibliography

1. Thielsch, Helmut, "Copper in Stainless Steel," Welding Council, *Bull. No. 9*, August 1951.

2. Roberts, R. R., "Metallurgy of Arc Welding Steels," Publication of the British Thomson-Houston Co. Research Laboratory.

3. Schaeffler, Anton L., "Constitution Diagram for Stainless Weld Metal," Metal Progress Data Sheet, November 1949, p. 680B.

The AEC Welding Committee

The Atomic Energy Commission has created a Welding Committee with F. W. Davis as Chairman. Mr. Davis has been active in the affairs of the American Welding Society, in the work of the ASME Boiler Code Committee, and the Pressure Vessel Research and High Alloys Committee of the Welding Research Council.

The AEC Welding Committee is made up of representatives from companies engaged in the construction and/or operation of plants and laboratories under contract with the Atomic Energy Commission. Meetings are held semiannually during which papers on classified welding projects are presented by members of the group and progress reports on current welding development programs are presented and discussed. The meetings afford members an opportunity for free discussion of their individual problems, many of which are classified for security reasons.

Members of the Committee receive notice of all welding research programs under way or contemplated by any of the individual contractors. In this manner, duplication of effort is avoided and the development accomplished by one contractor is made immediately available to all others engaged in the program.

A task force of the Committee is currently engaged in a review of welding standards and procedures developed by the various contractors. Some unification in this field is expected.

Another group is engaged in the investigation and study of failures of welding equipment which has been exposed to irradiation and/or highly corrosive service.

Data developed from AEC-sponsored research programs which are believed to be of value to industry in general will be declassified and made available for publication as rapidly as possible under security regulations.

The AEC Welding Committee works very closely with the Welding Research Council on special problems related to high alloys. A special Advisory Committee of the Council is currently guiding a program directed to the development of improved alloys for welding Type 347 stainless steel. This particular investigation is financed by the AEC. Although the project has not been completed, certain alloys have been developed which, on the basis of data thus far obtained, appear to offer promise of better service than that of commercially obtainable alloys, particularly for elevated temperatures. As a matter of fact, one of the large utility companies has requested and received permission to use two of the new alloys in commercial service tests.

The New Bridge Over the Rhine at Dusseldorf

THE new bridge, Fig. 1, replaces one which was destroyed by retreating German troops in 1945. Welding was employed for all shop fabrication. Field joints were riveted. The flooring consists of plates $^3/_4$ to $1^1/_8$ in. thick which were prefabricated into elements 25 x 38 ft. To reduce the amount of riveting at joints, reinforcing plates were welded, Fig. 2. The type of construction used in the bridge is shown in Figs. 3 and 4.

The weight of steel in the new bridge is 6969 tons, of which 5489 tons is a high-tensile steel of high weldability (HSB50 MES, see THE WELDING JOURNAL, 32 (1), 43 (1953)), 1353 tons is mild steel and 127 tons is cast steel. The HSB50 steel has high fatigue strength and improved weldability. The yield point is 41,000–47,000 psi; the tensile strength is 78,000 psi. The weld bead bend test results were excellent. There was no trouble in welding. Judicious welding sequence maintained distortion at a minimum. Submerged-arc and firecracker (Elin-Hafergut) processes were used. Prefabricated sections weighing up to 57 tons and measuring 75 ft long, $5^1/_2$ ft wide and 25 ft high were shipped to the bridge site. The bridge was erected in 8 months, cost 10.6 million German marks and is now the longest span, welded plate girder bridge in the world.

Abstract of "Reconstruction du pont sur le Rhin à Düsseldorf-Neuss," published in *L'Ossature Metallique*, **18**, 135-145 (March 1953). (Abstracted by Dr. G. E. Claussen.)

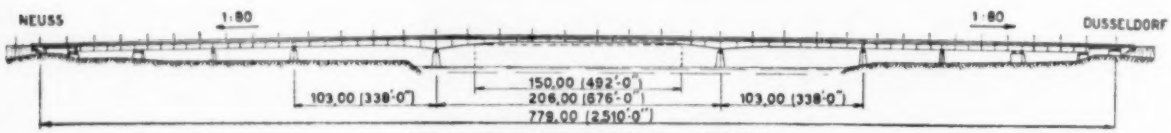


Fig. 1 The Dusseldorf-Neuss Bridge

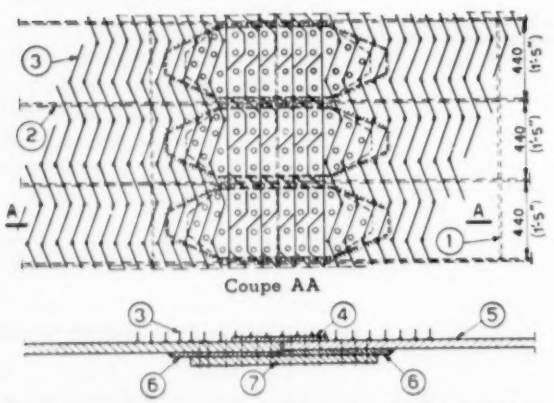


Fig. 2 Detail of a riveted field joint in the flooring showing welded reinforcing plates. They reduce the usual loss in section from 30% to only 5%

1, cross beam; *2*, longitudinal beam; *3*, zig-zag plates welded to the floor to support the asphalt; *4*, upper cover plate of the riveted joint; *5*, bridge floor; *6*, lower reinforcing plate welded to the floor; *7*, lower cover plate of the riveted joint.

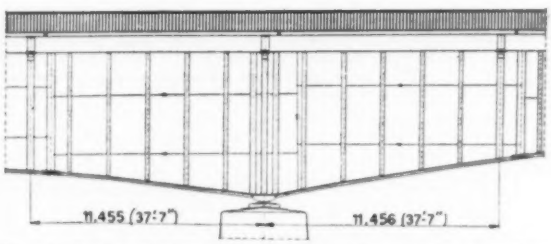


Fig. 4 External view of the plate girders over the piling

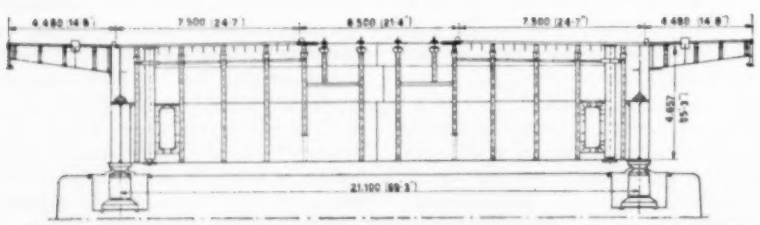


Fig. 3 Cross section showing the cross beam at the river piling. The bridge has two sidewalks, two roadways and two tram tracks

Newly Developed Glass Fiber Insulation gives longer trouble-free life to Jackson Holders

High heat, and, in many cases, high impact, make jaw insulators the most vulnerable parts of any arc welding electrode holder.

Jackson Products, pioneer manufacturer of insulated electrode holders, has time and again brought out worthwhile improvements in both the design and composition of holder insulators.

This time, here's the news: Not only the jaw insulators, but all the insulators on the entire line of Jackson Insulated Holders, are now made of an entirely new thermosetting material, all glass fiber reinforced, that exceeds in durability, by a wide margin, any material so far used for this purpose.

As a constant check on their quality, we have these insulators periodically tested by independent laboratories . . . not just sample bars of the same material, but the actual jaw insulators, completely fabricated, countersunk screw holes and all.

Compared to the jaw insulators previously used, these new pieces show greater strength under compression, more than twice the strength under flexure, and more than eight times the strength under impact. Electric furnace tests at temperatures of 500, 1,000 and 2,000° F. prove that the new Jackson Insulators retain their shape and their full insulative characteristics at temperatures well above those normally encountered.

More good news: These superior insulators are furnished on the holders at no extra cost, and as replacement parts at no increase in price. They still cost less than other makes.

New Holder AW-C with the new insulation, shown in detail above.

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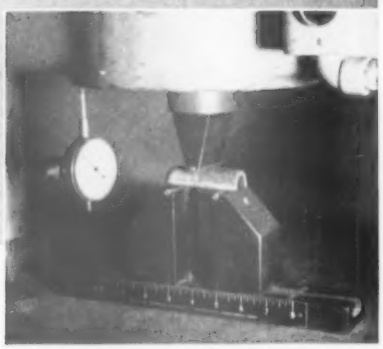
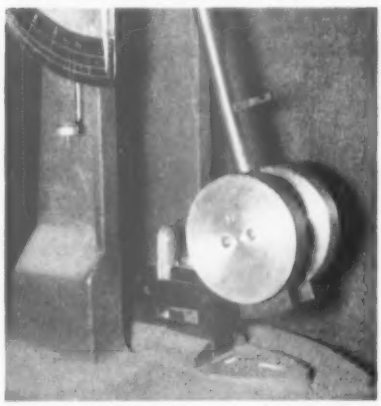
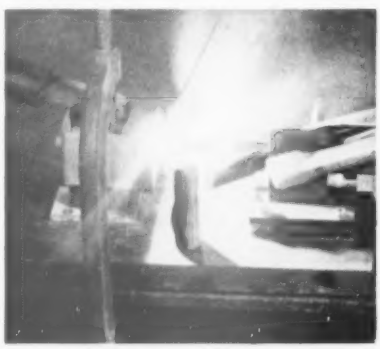


FLEXURE TEST shows insulator, supported two inches apart, with load applied downward at the center.



IMPACT TEST shows insulator, held vertical in vise, about to be hit by pendulum at 16 foot-pounds.



The CARBON ARC TEST is part of continuous quality control at Jackson's Plastics Department. The 1,300° F. heat applied by this method, at a distance of two inches from the test pieces, is comparable to the temperature normally radiated by two-inch electrode stubs.

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